Al-Khwarizmi Engineering Journal, Vol. 17, No. 4, December, (2021)
P. P. 1- 11

Al-Khwarizmi Engineering Journal

Comparison of Prediction Programs for Short Wave Circuit Link from Iraq to Test points on Both Earth Hemispheres during Solar Minimum

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(Received 8 August 2021; Accepted 5 October 2021)
https://doi.org/10.22153/kej.2021.10.003

Abstract

This paper compares the accuracy of the HF propagation's prediction programs for HF circuit links between Iraq and different points world wide during August 2018 when solar cycle 24 (start 2009 end 2020) was at minimal activity and also finds out the best communication mode used. Prediction programs like the Voice of America Coverage Analysis Program and the International Telecommunication Union Recommendation RS 533 had been used to generate high frequency circuit link parameters such as the Maximum Usable Frequency and Frequency of Transsmision. Depending on the predicted parameters (data), real radio contacts had been done using a radio transceiver from Icom model IC 7100 with 100W radiated power, tuner box and a homemade dipole antenna 10 meters in length and 8 meters in height above the ground. From the correlation between the predicted data and the observed data, the result was inaccurate.

Keywords: *FOT, MUF, minimum activity, Prediction programs.*

1. Introduction

The sun effects HF radio communication signals that are reflected from the ionosphere layers back to the earth. If the Solar Flux Index (SFI) increases, the layer's ionization will increase , causing the critical frequencies for these layers to increase too which makes higher frequencies transmitted diffract back to earth again [1]. According to eq(1) as the transmitted frequency increases, the more time it takes to fly in the ionosphere layers before getting refracted back to earth and hence ground distance increases [2,3]. To make a radio contact successfully on HF between two points, if a frequency is greater than the Maximum Usable Frequency (MUF), the signal will penetrate the ionosphere and escape to space and never come back to earth again ,so the working frequency must be less than the MUF and is called the Frequency of Transmission (FOT) [4]. The job of the prediction programs is to predict the FOT and MUF for any circuit link between two points at any time [5]. Most of the prediction program results are approximately convergent with points of one hop distance while they diverge (with acceptable error) in points with multiple hop distances, especially in points located near the geomagnetic equator line [5–7]. Most of these programs use input variables such as the Sun Spot Number (SSN) , date, geographical location, and the antenna type for prediction [6], and do not use important variables like K and A [8] even though the K parameter represents the status of solar winds. If these solar winds strike the ionosphere, it will result in an increase in the ionization level of the D layer causing an increase in the absorption, fading of sky wave signals, and even block out propagation for extreme solar winds intensity

[9]. The A parameter is a linear variable that represents the magnetic field of the earth. The previous papers [1-10] focused on the comparison of prediction programs at different geomagnetic circuits and different solar activity without mention to the Iraqi HF circuit link, while [11,12] studied the ionospheric parameters for Iraq's zone only when solar winds were at their maximum. The novelty of this work is studying and comparing the propagation prediction for the HF circuit link from Iraq to the world at the solar wind's minimum using the Voice of America Coverage Analysis Program (VOACAP), ITU Recommendation RS 533 (REC533), and real radio contact during August 2018; and also to find which modulation is preferred digital mode like FT8 [13] or analogue.

$$n^2 = 1 - \left(\frac{fp}{f}\right)^2 \qquad \ldots(1)$$

Where n is the refraction index, fp is plasma frequency, and f is transmitted frequency.

2. Methodology

In this paper, the ITS HF propagation analysis package will be used which includes the VOACAP, ICEPAC, REC533 and HFant programs. These programs will generate outputs such as the MUF, FOT, antenna take off angle, reliability of the link (REL), and the antenna analysis (and so on). To use the VOACAP or REC533 programs as shown in Figs. 1 and 2, choose the method of prediction (variables to be predicted like MUF,FOT,…..etc), set the year , time , groups (date and Sun Spot Number (SSN)), transmitter and receiver locations, frequency, system parameters, and transmitter receiver antenna (antenna type 23 horizontal dipole will be chosen) . For more information use the "Help" page in the program. Figs. 3 and 4 show a sample of the program's results, in which the MUF and FOT will be predicted at every hour in Greenwich Mean Time (GMT). To simulate the homemade antenna, the HFant program will be used first before the VOACAP and REC533, so the simulated result will be used in the predicted program for antenna part. Fig. 5 shows the program's interface which is simple to use, just enter the frequency of interest, antenna height, antenna length, and antenna gain. Fig. 6 shows the result of the simulation.

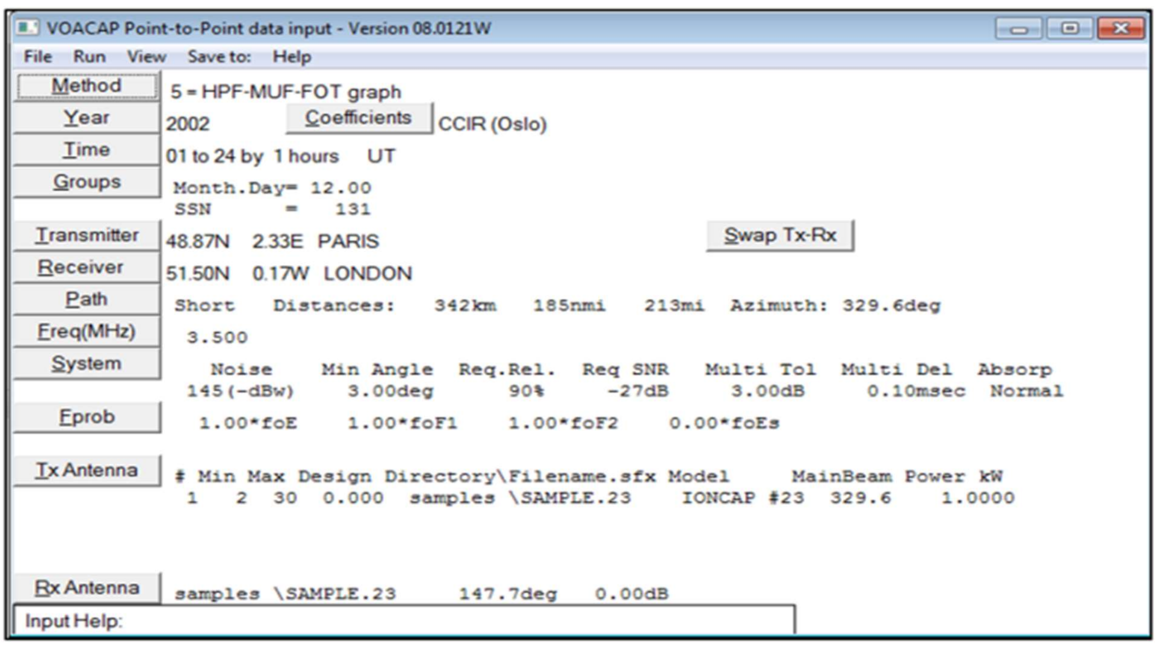

Fig. 1. Shows VOACAP program interface.

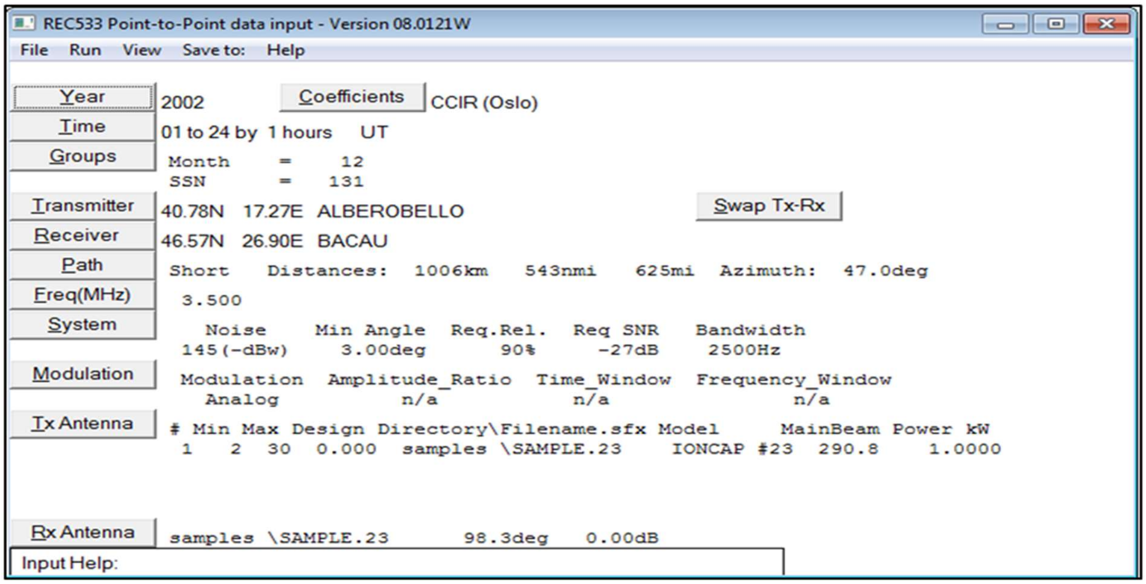

Fig. 2. Shows REC533 program interface.

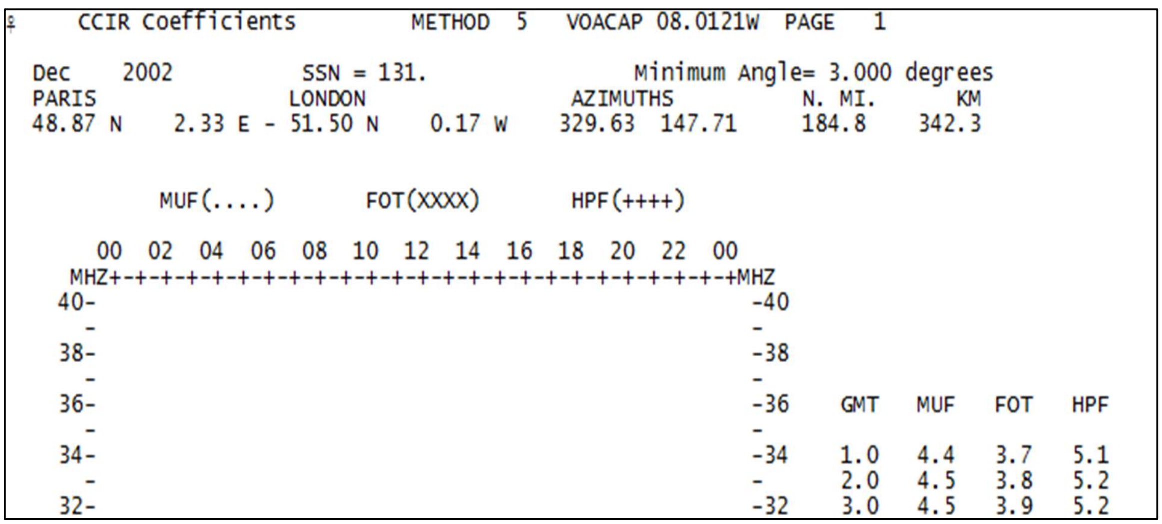

Fig. 3. Shows sample of VOACAP predicted result.

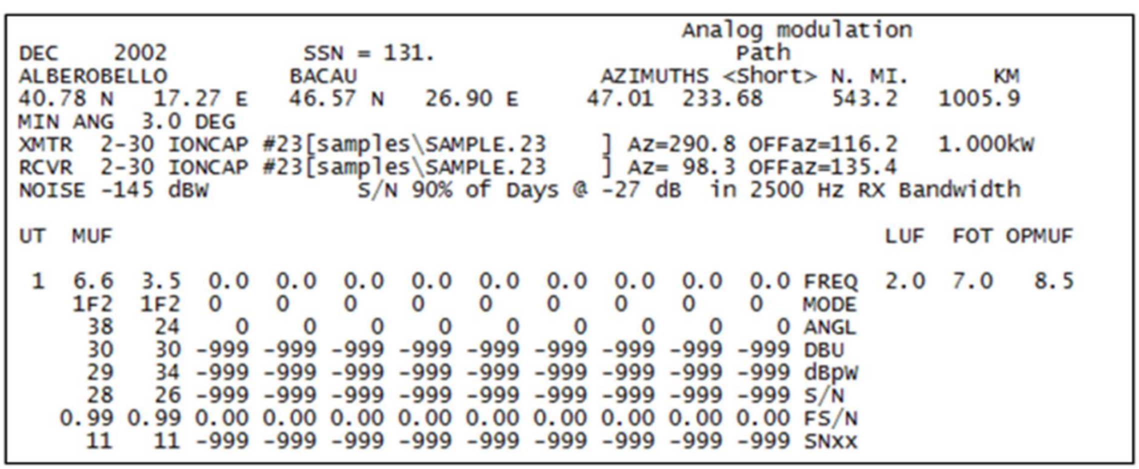

Fig. 4. Shows sample of REC533 predicted result.

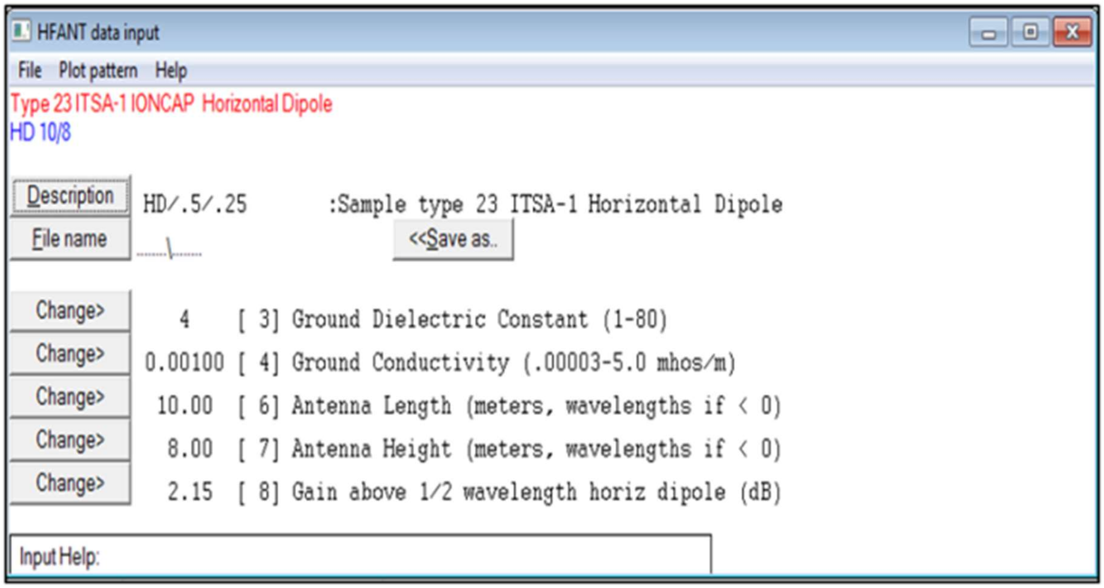

Fig. 5. Shows HFant program interface.

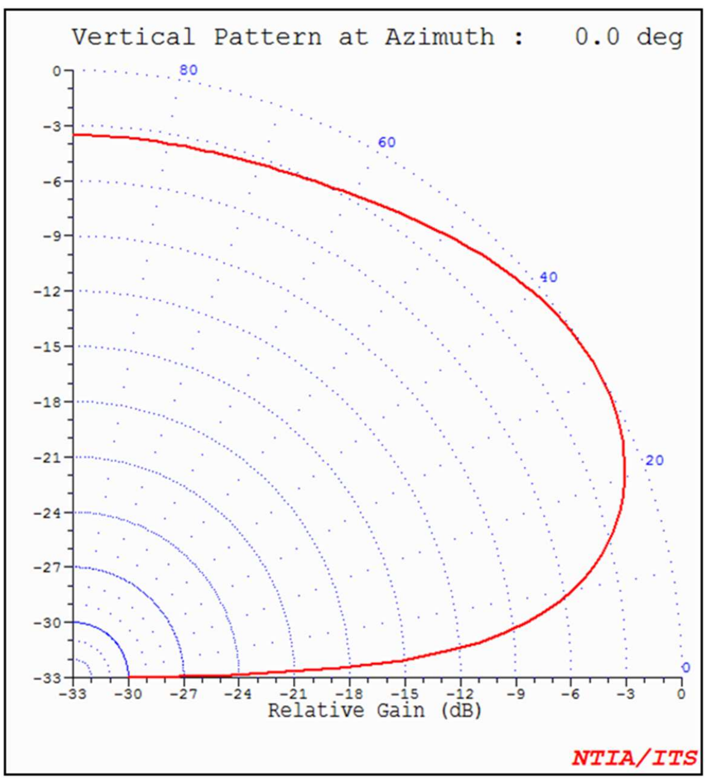

Fig. 6.a Shows HFant **result (vertical pattern) with maximum beam at 31 deg.**

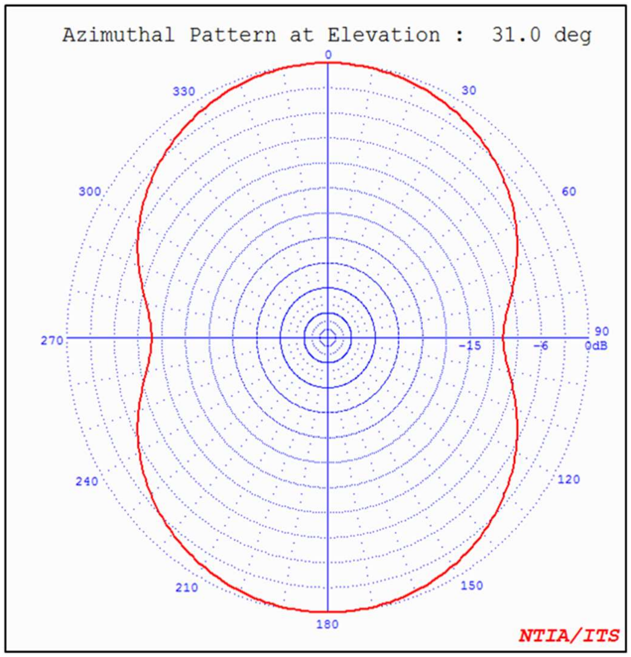

Fig. 6.b Shows HFant results (azimuth pattern).

Fig (6) shows the vertical and azimuth antenna pattern. Antenna gain is 2.15 dBi with main beam raised to approximately 31 deg . (In vertical direction) above the ground with the beam width in the azimuth's direction approximately 270 deg.

3. Experiments and Results

The locations of High Frequency (HF) circuit links between Iraq and points located on both earth hemispheres shown in table 1 had been studied using prediction programs like VOACAP and REC533 during May 2014 (where solar cycle 24 was at its maximum and take Iraq- Argentina HF circuit link as example) and August 2018 (when the solar cycle was at its minimum) and the results were summaized on figs. 7-13. These points had been chosen according to their hopping distances (one hop, multi-hop) from Iraq and non-arbitrarily. The predicted variables were the Maximum Usable Frequency (MUF) and Frequency of Optimum Transmission (FOT). A correlation between the predicted MUF and the predicted FOT that was generated using VOACAP and REC533 had been done as a measure of accuracy and is summarized in table 2. Table 3 summarizes the critical frequency of the F2 layer (foF2) that was generated by using the VOACAP prediction program (F2pred) for the point (50.1N, 4.6E) Dourbes in Belgium for 8/1/2018 and the observed foF2 (F2obs) that was recorded using the Ionosonde station in Dourbes in Belgium (50.1N, 4.6E) . A correlation between F2pred and F2obs is summarized in fig. 14. Depending on the predicted data from figs. 8 to13, a real radio contact had been done using the radio transceiver from the Icom model IC-7100 with 100 W power, Single Side Band (SSB), and a digital modulation mode like the Franke–Taylor design, 8 FSK modulation (FT8) [13] had been used and a tuner box from MFJ model MFJ-945E as impedance matching box as shown in fig. 15. The antenna was a homemade dipole antenna which was 10 meters long and was rotated manually toward the destination point with a height of 8 m above the ground made with wire with 2.5 mm. in diameter (see fig. 16). Table 4 summarizes the contact information that occurred. The Mean Square Error (MSE) had been done between the predicted FOT (FOTpred) from VOACAP and REC533 and observed FOT (FOTobs) that get by real radio contact and summarized the result in table 5.

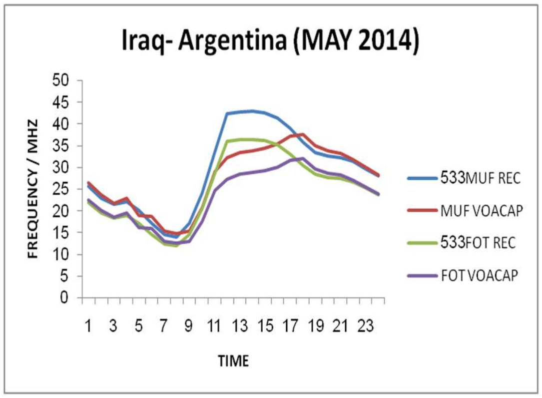

Fig. 7. Shows Iraq- Argentina HF circuit link prediction at solar maximum.

Fig. 7 shows that predictions of using higher bands for skywave radio communication for the Iraq-Argentina circuit link during solar maximum with the height ionozation level for the ionospher layer (F2) using both VOACAP and REC533 programs are high.

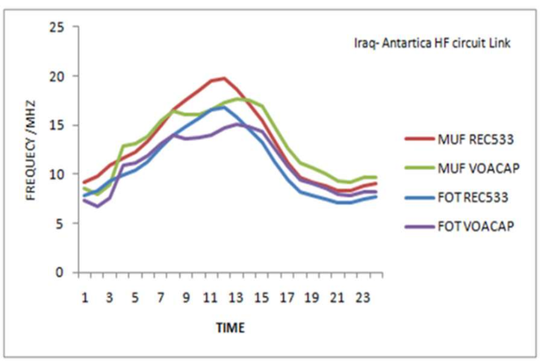

Fig. 8. Shows Iraq- Antarctica HF circuit link prediction.

Fig. 8 shows the MUF and FOT predicted by VOACAP and REC533, starting with low values and increased with sun rising (increasing of the ionization level of ionosphere layers) and reached its maximum values at mid day then decreased again at sun set. Fig. 8 shows that data predicted by REC533 is higher than VOACAP predicted data.

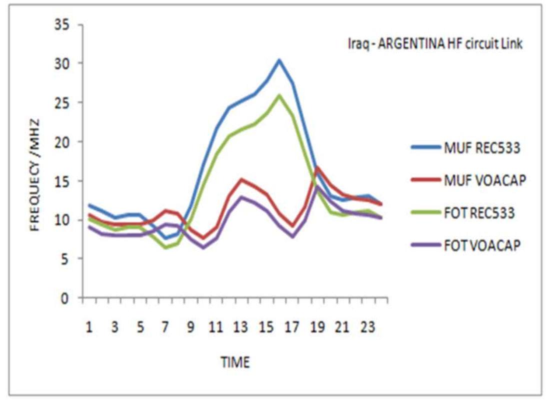

Fig. 9. Shows Iraq-Argentina HF circuit link prediction.

Fig. 9 shows the MUF and FOT predicted by VOACAP and REC533, starting with low values and increases as the sun rises (increasing of ionization level of ionosphere layers) and it reached its maximum values at mid day then decreased again with the sunset. Fig. 9 shows that predictions for the MUF and FOT values that are generated by REC533 are higher than the VOACAP predictions.

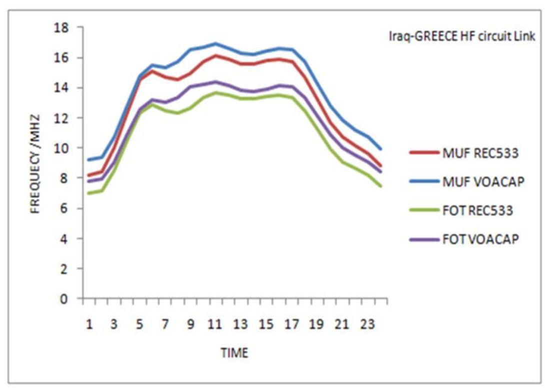

Fig. 10. Shows Iraq- Greece HF circuit link prediction.

Fig. 10 shows the MUF and FOT predicted by VOACAP and REC533, starting with low values and increases as the sun rises (increasing of ionization level of ionosphere layers), it reached its maximum values at mid day then decreased again with the sunset. Fig. 10 shows that predictions for the MUF and FOT values that are generated by VOACAP are higher than the REC533 predictions.

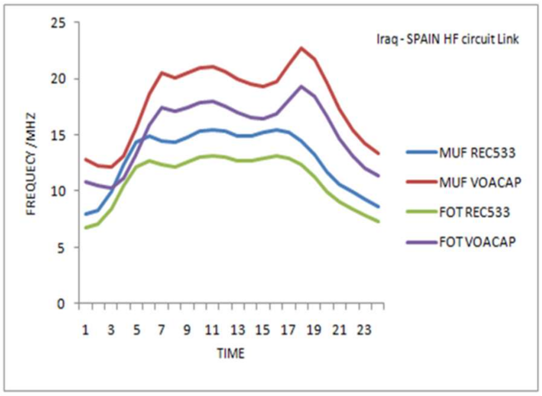

Fig. 11. Shows Iraq- Spain HF circuit link prediction.

Fig. 11 shows the MUF and FOT predicted by VOACAP and REC533. Itstarts with low values and increases as the sun rises (increasing of ionization level of ionosphere layers) and reaches its maximum values at mid day and then decreases again with the sunset. Fig. 11 shows that predictions for the MUF and FOT values that are generated by VOACAP are higher than the REC533 predictions.

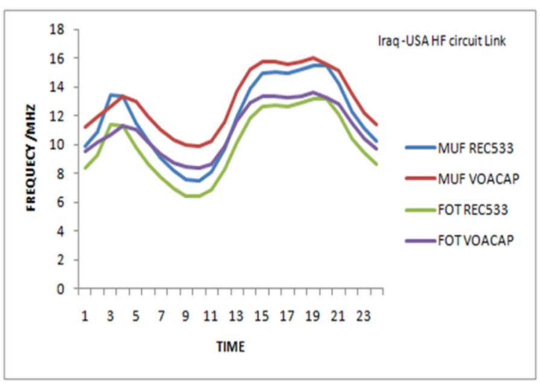

Fig. 12. Shows Iraq- USA HF circuit link prediction.

Fig. 12 shows the MUF and FOT predicted by VOACAP and REC533, it starts with low values and increases as the sun rises (increasing of ionization level of ionosphere layers) and reaches its maximum values at mid day then decreases again with the sunset. Fig. 12 shows that the predictions for the MUF and FOT values that were generated by VOACAP are higher than the REC533 predictions.

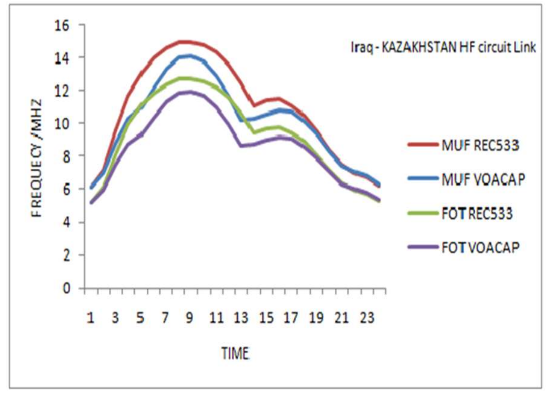

Fig. 13. Shows Iraq- Kazakhstan HF circuit link prediction.

Fig. 13 shows MUF and FOT predicted by VOACAP and REC533, starting with low values and increases as the sun rises (increasing of ionization level of the ionosphere layers) and it reached its maximum values at mid day and then decreased again with the sunset. Fig. 13 shows that predictions for the MUF and FOT values that are generated by REC533 are higher than the VOACAP predictions.

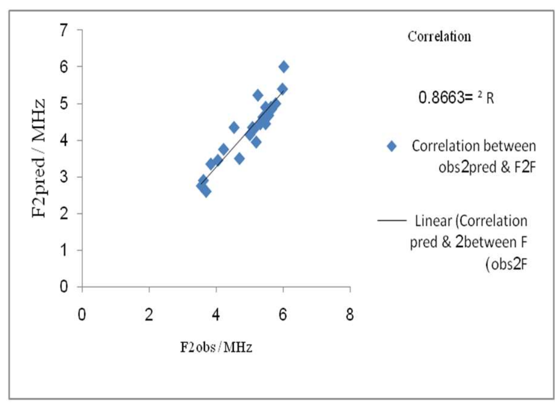

Fig. 14. Showscorrelation between F2pred and F2obs for Dourbes –Belgium.

Fig. 14 shows the correlation between the F2pred of fof2 that was predicted by VOACAP and the F2obs that was measured by the Dourbes Ionosonde station in Belgium during 8/1/2018 for the point (50.1N, 4.6E). The correlation was high, around 0.930752.

Fig. 15. Shows Icom transceiver model IC-7100 with tuner box from MFJ model MFJ 945E.

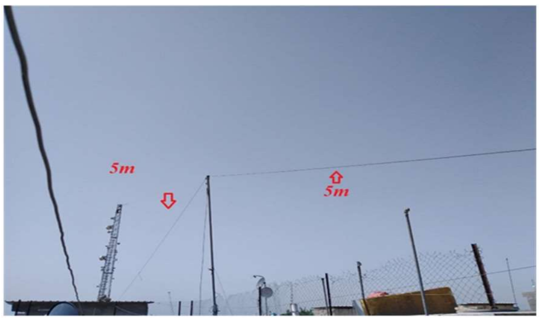

Fig. 16. Shows dipole antenna of 10m long,8m height above groundTable 1 shows HF circuit points geographical locations.

Table 1,
Shows HF circuit points geographical locations.

Test point	Latitude	Longitude
Iraq	32.77N	44.28E
Antarctica	70.77S	11.79E
Spain	41.16N	1.10E
Argentina	32.05S	59.43W
Greece	37.40N	22.72E
Kazakhstan	43.64N	51.15E
USA	33.65N	112.38W

Table 2,
Shows the correlation between REC533 & VOACAP

Country	MUF CORRELATION
ANTARTICA	0.934212198
SPAIN	0.836102864
ARGINTENA	0.25146955
GREECE	0.994734886
KAZAKHSTAN	0.98365713
USA	0.974518472

Table 3,
Shows the fof2 predicted and measured for Dourbes in Belgium

UTC	*Fof2* /MHZ pred (VOACAP)	obs (Dourbes ST.)
1	3.84	3.35
2	3.62	2.9
3	3.56	2.75
4	3.7	2.6
5	4.05	3.45
6	4.53	4.35
7	5	4.15
8	5.31	4.45
9	5.47	4.9
10	5.56	4.68
11	5.63	4.9
12	5.62	4.85
13	5.47	4.45
14	5.24	5.23
15	5.08	4.35
16	5.12	4.3
17	5.39	4.63
18	5.77	5
19	6.01	6.01
20	5.97	5.4
21	5.65	4.85
22	5.19	3.95
23	4.69	3.5
24	4.22	3.75

4. Discusion

From the predicted and observed data, the following notifications had been observed, as follows:

The REC533 and VOACAP programs gave predictions to use high frequency bands for the skywave radio communication HF circuit link between Iraq and the world even at the solar cycle's minimum with Solar Flux Index (SFI) < 70 (ionozation levels for F2 layer is low). The VOACAP predictions gave higher predicted values than REC533 at the nothern earth hamsphere except at Kazakhstan, while REC533 gave higher predicted values at the southern earth hemisphere. According to table (2) , the two prediction programs had higher correlation values except for the Iraq-Argentina circuit link (R=0.25146955) because according to Fig. 9, the REC533 prediction program's MUF curve had one maximum point that occurred at 16 UT. whereas for VOACAP the curve had two minimum points that occurred at 10 UT and 17 UT and one maximum point that occurred at 13 UT. The correlation was in this period around (0.21470911) meaning that the REC533 assumes the Iraq-Argentina circuit link exists in the same day zone while VOACAP assumes the link exist between night–day., day day zone which is more accurate and explains the variance in the two MUF/FOT curves. According to fig. 14, there is a high correlation (R= 0.930752) between F2pred and F2obs for the Dourbes point in Belgium [14]. According to table 5, even that the most of the predicted FOT failed compared to the observed FOT. The REC533 prediction is more accurate than VOACAP. According to [15], both prediction programs do not include geomagnetic activity variables like K as an input to the prediction. According to table 4, digital mode (FT8) works well (can propagate well) than analogue mode (SSB) during solar minimum because it has narrow bandwith around 50Hz , S/N around -21dB and fast its TX/RX simplex transmission round about 15sec.

5. Conclusions

In this paper, the HF circuits links between Iraq and points located on both earth hemispheres with different hops had been studied using VOACAP and REC533 during August 2018 (solar cycle's minimum). A correlation between the predicted data that was generated had been done as a measure of accuracy. Real radio contacts had been established based on the predicted results using a transceiver from Icom model IC-7100 and a 10 meter dipole raised up with 8m rotated manually. Most of the FOTs used in real radio contacts diverge from the FOTpred not as a problem in prediction programs algorithms but there was no observed foF2 data given from points like Iraq to support the prediction programs models because Iraq has no Ionosonde station. According to the MSE, the REC533 prediction showed more accuracy than the VOACAP prediction program. During the solar cycle's minimum with low sun activity, propagation using digital mode (FT8) is better than analogue (SSB) for one hop or more. Finally VOACAP and REC533 will predict with high probability in regions with Ionosonde stations like in Dourbes, Belgium, and predict with low probability with regions with no Ionosonde stations like in Iraq and the Middle East.

Acknowledgment

Ahmed Kadhim, the author thanks Space Weather Services (SWS) of The Bureau of Methodology /Australian government for supporting the research by data (SSN values) used in prediction programs

Table 4,
Summarizes the contact information.

Station A	Latitude	Longitude	Station B	Latitude	Longitude	Date	Time /UTC	Frequency/ KHz	Mode	Signal/ dBuV
Iraq	32.77N	44.28E	Antarctica	70.77S	11.79E	8/25/2018	14:13	18102.244	digital/FT8	-21
			Spain	41.16N	1.10E	8/25/2018	22:12	7074.1	digital/FT8	-18
			Argentina	32.05S	59.43W	8/24/2018	20:14	14074.961	digital/FT8	-4
			Greece	37.40N	22.72E	8/28/2018	16:20	14200	analogue/SSB	22
			Kazakhstan	43.64N	51.15E	8/28/2018	7:10	18100	digital/FT8	-19
			USA	33.65N	112.38W	8/25/2018	20:11	14076.6	digital/FT8	-3

Table 5,
Shows the MSE between real contact data and predicted data

station A	station B	FOT pred KHz		FOT obs KHz	MSE VOACAP KHz	MSE REC533 KHz
		VOACAP	REC533			
Iraq	Antarctica	14875	14620	18102.244	16.25756812	9.455438783
	Spain	13175	8415	7074.1		
	Argentina	12325	11050	14074.961		
	Greece	14110	13515	14200		
	Kazakhstan	11305	12410	18100		
	USA	13260	13175	14076.6		

6. References

[1] R. Athieno, P. T. Jayachandran, D. R. Themens, and D. W. Danskin, “Comparison of observed and predicted MUF (3000) F2 in the polar cap region,” Radio Sci., vol. 50, no. 6, pp. 509–517, 2015.

[2] Australian Government - IPS Radio and Space Services, “Introduction to HF Radio Propagation,” 2010. [Online]. Available: https://www.sws.bom.gov.au/Educational/5/2/2. [Accessed: 04-Sep-2021].

[3] C. Mudzingwa, A. Chawanda,"Radio Propagation Prediction for HF communications",communications,vol 6,no. 1 pp. 5-12,2018

[4] I. Bouleanu, M. Gheorghevici, and R. Helbet, “The quality of the prediction for the NVIS propagation with ITS-HF propagation,” EEA - Electroteh. Electron. Autom., vol. 64, no. 1, pp. 97–104, 2016.

[5] N. Insakun, N. Wichaipanich, and K. Hozumi, “Comparison of M (3000)F2 Variation between Measured Data by Ionosonde and IRI-2016 Model Data over Chiang Mai, Thailand,” 17th Int. Conf. Electr. Eng. Comput. Telecommun. Inf. Technol. ECTI-CON 2020, no. 3000, pp. 197–200, 2020.

[6] E. E. Johnson, “NVIS Communications During the Solar Minimum,” in MILCOM, Military Communications Conference, 2007, pp. 1–5.

[7] R. A. Malik, M. Abdullah, S. Abdullah, and M. J. Homam, “The influence of sunspot number on high frequency radio propagation,” 2014 IEEE Asia-Pacific Conf. Appl. Electromagn. APACE 2014 - Proceeding, pp. 107–110, 2015.

[8] M. C. Walden, “Analysis of chilton ionosonde critical frequency measurements during solar cycle 23 in the context of midlatitude hf nvis frequency predictions,” IET Conf. Publ., vol. 2012, no. 594 CP, p. 41, 2012.

[9] H. Wang and Y. Zou, “Comparison of the Ionospheric F2 Region Critical Frequency between Ionosonde Measurements and IRI-2016 Predictions over Sanya,” 2018 12th Int. Symp. Antennas, Propag. EM Theory, ISAPE 2018 - Proc., pp. 1–4, 2019

[10] A. J. Stocker, “Fast and accurate calculation of multipath spread from VOACAP predictions,” Radio Sci., vol. 47, no. 4, pp. 1–10, 2012.

[11] K. A. Hadi,L. E. Goerge ," A simplied Mathematical Model to Calculate the Maximum Usable Frequencies Over Iraqi Territory", Diyala Journal For Pure Sciences,vol 7, no. 4 ,pp 120,2011.

[12] A. Z. Aziz , K. A. Hadi, "Determination of Ionospheric Parameters over Iraqi Zone", Iraqi Journal of Science, vol 54, no.2, pp 475-484, 2013.

[13] Dale Burmester, “Amateur Radio Digital Communication Mode FT8,” 2019. [Online]. Available: http://site.ieee.org/msn/files/2019/04/FT8-KA9SWE.pdf. [Accessed: 07-Sep-2021].

[14] S. G. Tanyer , C. B. Erol,” comparison of the Current Method s for Coverage Area Prediction for Communication in the HF Band”, IEEE antenna and propagation society international symposuim,1998.

[15] A. J. Stocker, M. Muriuki, E. M. Warrington,” comparision of Obliques sounding measurements and VOACAP

[16] predictions on a mid – latitude path”, The Institution of Engineering and Technology 11th International Conferrenceon Ionosperic radio systems and Techniques, 2009.

مقارنة برامج التوقع لمسارات دوائر الموجات القصيره من العراق الى نقاط اختبار على جانبي نصفي الكره الارضيه خلال الدوره الشمسيه الصغرى

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الخلاصة

هذا البحث يقارن دقة برامج التوقع لمسارات دوائر الموجات القصيره بين العراق ونقاط مختلفة خلال الشهر الثامن ٢٠١٨ عندما الدوره الشمسيه ٢٤(بدات ٢٠٠٩ وانتهت ٢٠٢٠) كانت عند اقل نشاط وكذلك ايجاد افضل نمط اتصال مستخدم. برامج التوقع مثل:
Voice of America Coverage Analysis Program (VOACAP) and ITU Recommendation RS 533 (REC533)
استخدمت لتوليد متغيرات مسار دائرة الموجة القصيرة مثل اعظم تردد مستخدم والتردد العامل. بالاعتماد على هذه المتغيرات (البيانات) تم عمل اتصالات راديوي باستخدام لاسلكي من شركة ايكوم موديل ٧١٠٠ بقدره ١٠٠ واط و صندوق مؤائمه وهوائي دايبول صنع يدوي بطول ١٠ متر وارتفاع ٨ متر عن مستوى الارض. من عملية التطابق بين البيانات المتوقعه و البيانات المقاسة النتائج كانت غير دقيقة.