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RESEARCH ARTICLE

EMPIRICAL MUTUAL CORRELATION FORMULA FOR SEASONAL IONOSPHERIC PARAMETERS VARIATION OVER MIDDLE EAST REGION.

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Abstract

In this project,the behavior of ionospheric parameters has been studied for the seasonal times of the years (2009 & 2014) of solar cycle 24.A mutual correlation formula between the ionospheric parameters, maximum usable frequency (MUF), optimum workable frequency (OWF) & lowest usable frequency (LUF) have been suggested for the communication links distributed over Middle East Region. The values of the MUF and OWF parameters were generated from the international communication HF model (ASAPS) for the Minimum and Maximum of solar cycle 24, While the LUF parameter was generated using the (REC533) international communication model. The tested correlation coefficients between these parameters showed a good correlation with each other. The suggested formula gave a good fitting between the present values and the generated data of the international model and the international recommended criterion (theoretical).

Introduction:-

In the Earth's atmosphere, the ionosphere is the part of the Earth’s upper atmosphere that makes up less than one percent of the mass of the atmosphere above 50 km. It extends from about 50 km altitude to about 1000 km and more where it merges with near Earth space environment. The ionosphere contains charged particles due to intense UV radiations from the sun.In the day there may be four regions present called the D, E, F1 (lower) and F2 (upper) regions. At night the D, E and F1 regions become very much depleted of free electrons, leaving only the F2 region available for communications [1]. The Radio signals affects by the ionosphere in different ways depending on their frequencies. On frequencies below about 30 MHz the ionosphere may act as an efficient reflector, allowing radio communication to distances of many thousands of kilometers [2]. Radio signals on frequencies above 30 MHz usually penetrate the ionosphere and, therefore, are useful for ground-to-space communications. High frequency (3 to 30 MHz) radio signals can propagate to a distant receiver. Figure (1), via the following methods [3]: Propagation is by ground, direct and sky wave.

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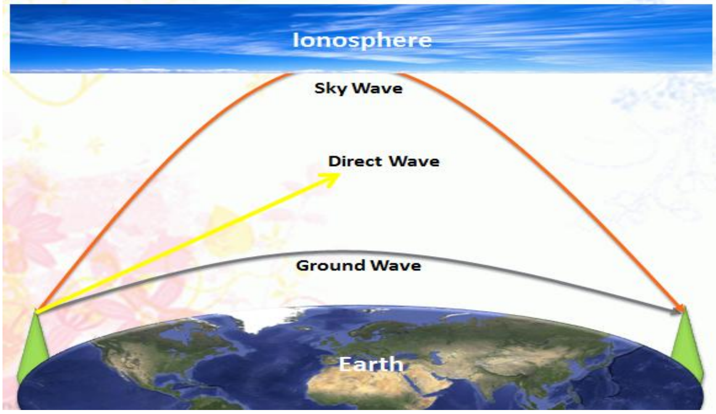


Figure 1:- Types of HF propagation.

The Ionospheric Communication Parameters:-

The ionospheric parameters are defined as the best operation frequencies that are propagated through ionosphere, so these parameters can be defined as:-

Maximum Usable Frequency (MUF) is the highest ionospheric frequency which can be used to maintain successful communication link only 50% of the time over a particular path under given ionospheric conditions between two sits.

Optimum Working Frequency (OWF) is the optimum reliable frequency can be reflected from ionosphere layer that is worked only 90% for specific time [4].

Lowest Usable Frequency (LUF) is the lower frequency that allows reliable long-range HF radio communication between two points by ionospheric refraction that is worked only 10% of the days of the month at a given time of day on a specified path [5].

The above parameters are greatly changed with several factors like solar cycle, spatial and temporal scales that have strong influence on the state of the ionosphere layer. [6].

The International Communication Model:-

The dataset of the required ionospheric parameters over the Middle East region have been calculated using the REC533 and ASAPS international models. The REC533 propagation prediction model which used for estimating the reliability and compatibility between frequencies of about 3 - 30 MHz. This implementation represents one of the modern radio broadcasting versions of ITU. ASAPS model which considered as one of the most accurate and advanced HF sky wave propagation models allow the prediction of Sky Wave communication conditions in the HF radio spectrum or Short Wave Band (1 to 45 MHz) that based on an Ionospheric model, developed by IPS Radio and Space Services of the Australian Bureau of Meteorology and ITU-R / CCIR models.

Datasets Analysis:-

The variation and behavior of the ionospheric parameters have been studied in order to get the mutual correlation between these parameters for the seasonal time of the years 2009 & 2014 of solar cycle 24 between HF communication terminals that distributed over Middle East Zone. Baghdad city (44.42^{o}E, 33.32^{o}N) has been select to represent a transmitter station while sixty-five locations that spread over Middle East Zone have been considered as a receiver station, as shown in figure (2).

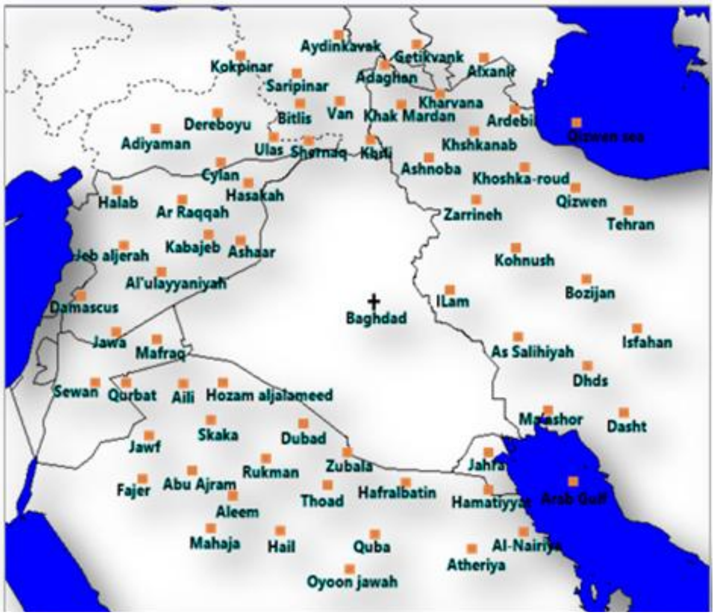


Figure 2:- The location of a transmitter and receiver stations over Middle East zone.

The datasets of the LUF ionospheric parameter have been determined using the REC533 international communication models, while the MUF and OWF parameters have been calculated using ASAPS international communication models. The monthly-observed sunspot number (SSN) for the years of 2009 and 2014 which have been chosen to be the studied years, because these years represent the beginning and the peak of solar cycle 24. Figure (3) shows the values of the observed sunspot number for each month of the selected years of solar cycle 24.

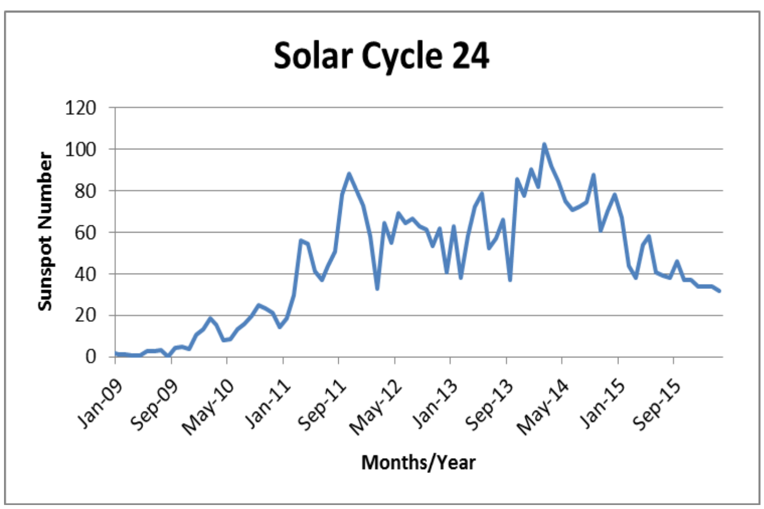


Figure 3:- Observed Sunspot Number of Solar Cycle 24 [7].

The geographical location coordinates (longitude and latitude), spherical geodesic parameters (path length - bearing transmitter to receiver (T_x to R_x) and bearing receiver to transmitter (R_x to T_x)) and distance for connection links over the Middle East Region have been calculated using a matlab program language illustrate in table (1).

Table 1:- The Geographical Location and Geodesic Parameters for all Receiver Station.

Receiver station	Location		Distance (Km)	Path length (Rad)	Bearing		Receiver station	Location		Distance (Km)	Path length (Rad)	Bearing	
	Long. (E)	Lat. (N)			Tx to Rx	Rx to Tx		Long. (E)	Lat. (N)			Tx to Rx	Rx to Tx
Ilam	46.240	33.380	169.170	0.027	88.180	272.320	Halab	37.800	36.120	680.220	0.107	117.120	297.120
Kharvana	46.100	38.400	584.770	0.091	196.890	343.600	ArRaqqah	38.590	35.570	590.110	0.093	114.930	294.930
Zarrineh	47.100	36.400	420.760	0.066	143.800	323.800	Damascus	36.170	33.300	766.450	0.119	89.990	269.990
Ashnoba	45.510	37.200	442.630	0.069	166.520	346.520	Jeb aljerah	37.180	34.480	680.370	0.106	100.700	280.700
Kohnush	48.160	34.430	366.640	0.058	71.370	252.420	Al'ulayyaniyah	38.350	33.500	563.690	0.088	91.700	271.700
Qizwen	49.590	36.160	568.090	0.089	123.280	303.280	Kabajeb	39.400	35.400	515.480	0.081	113.860	295.280
Tehran	51.250	35.410	668.400	0.105	109.960	289.960	Jawa	37.900	32.350	618.520	0.096	100.400	280.400
Ardebil	48.160	38.150	634.200	0.099	147.420	327.420	AL-Qurbat	37.220	31.190	717.080	0.112	109.630	289.630
As Salihiyah	48.210	32.270	372.970	0.059	108.540	288.540	Hozamjalamed	40.600	31.160	432.100	0.067	124.410	304.410
Ma'ashor	49.110	30.330	553.850	0.087	126.920	306.920	Al Jawf	38.100	29.570	730.030	0.114	125.210	305.210
Isfahan	51.400	32.390	660.010	0.104	99.240	279.240	AL-Dubad	42.180	30.140	412.170	0.064	149.760	329.760
Dasht	51.160	30.320	718.660	0.113	114.910	296.690	Hail	41.410	27.300	728.980	0.114	157.040	337.040
Bozijan	50.140	33.550	531.320	0.083	92.380	272.380	Abu Ajram	39.140	29.100	687.050	0.107	133.490	313.490
Dhds	50.170	31.420	579.760	0.091	111.540	291.540	Hafralbatin	45.120	28.430	547.820	0.086	187.660	352.520
Khoshka-roud	48.310	36.480	499.220	0.078	134.160	314.160	Quba	44.200	27.240	676.390	0.106	178.040	270.170
Adaghan	44.360	39.240	658.290	0.102	180.150	359.990	Al-Hamatiyyat	47.350	28.360	618.320	0.097	150.890	241.650
Khshkanab	47.700	37.420	544.230	0.085	146.370	326.370	Al-Nairiya	48.290	27.280	767.350	0.120	148.710	239.700
KhakMardan	45.400	38.230	553.060	0.086	170.370	350.370	AL-Rukman	41.160	29.200	552.990	0.086	146.450	326.450
Van	43.220	38.290	563.110	0.087	169.210	349.210	Skaka	39.440	30.280	579.310	0.090	126.170	306.170
Khrli	44.150	37.290	442.120	0.068	177.270	357.270	Mahaja	39.450	27.340	818.060	0.128	144.710	324.710
Saripinar	42.800	39.120	661.060	0.103	167.540	347.540	Oyoonjawah	43.370	26.370	779.390	0.122	172.840	352.840
Kokpinar	40.340	39.390	767.270	0.120	148.230	329.450	Fajer	37.510	28.490	849.940	0.133	129.510	309.510
Ceylan	40.400	36.550	513.000	0.079	134.440	314.440	Zubala	43.320	29.320	456.870	0.072	167.330	347.330
Adiyaman	38.120	37.460	733.200	0.114	128.860	308.860	AL-Thoad	43.000	28.400	563.590	0.088	163.810	255.180
Shernaq	42.270	37.300	483.600	0.076	153.610	334.230	AL-Aleem	40.230	28.240	692.140	0.108	145.100	325.100
Ulas	41.320	37.340	528.020	0.083	144.640	325.550	Al-Atheriya	47.200	27.200	730.920	0.115	156.730	337.430
Bitlis	42.150	38.250	585.120	0.091	159.740	339.740	AL-Aili	38.590	31.150	598.960	0.093	114.190	294.190
Dereboyu	39.560	38.100	689.000	0.107	140.520	320.520	Jahra	47.360	29.300	527.020	0.083	147.850	327.850
Getikvank	45.300	39.560	698.290	0.110	172.620	352.890	Mafraq	38.180	32.250	595.230	0.092	101.910	281.910
Aydinkavak	43.190	40.110	762.900	0.119	171.970	351.970	Sewan	36.340	31.160	796.710	0.124	107.850	287.850
Al Hasakah	40.470	36.240	485.260	0.076	131.980	311.980	Alxanli	39.350	27.230	833.730	0.130	144.640	324.640
Ashaar	40.330	34.550	401.300	0.062	109.650	289.650	Arab Gulf	49.510	28.470	725.520	0.114	135.140	226.460

The seasonal variation of the ionospheric parameter has been investigated for four seasons. Each season represents a seasonal months for a specific studied area. For Middle East zone the seasonal months classified according to the following table (2).

Table 2:- The classification season time.

	Season	Months
1	Winter	December – January – February
2	Spring	March – April – May
3	Summer	June – July – August
4	Autumn	September – October – November

The seasonal variation of the ionospheric parameters has been performed for all selected receiver stations over the tested area. Figures (4) & (5) show the analytical result of the MUF, OWF and LUF parameters for seasonal time of the years 2009 and 2014.

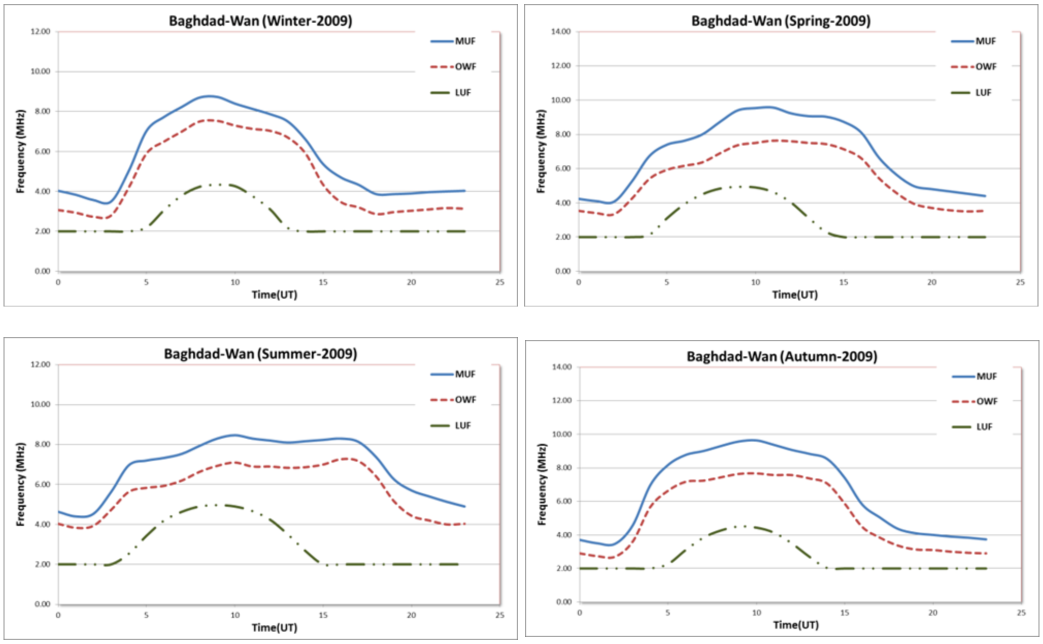


Figure 4:- Seasonal variation of ionospheric parameters (MUF, LUF & OWF) for the year 2009.

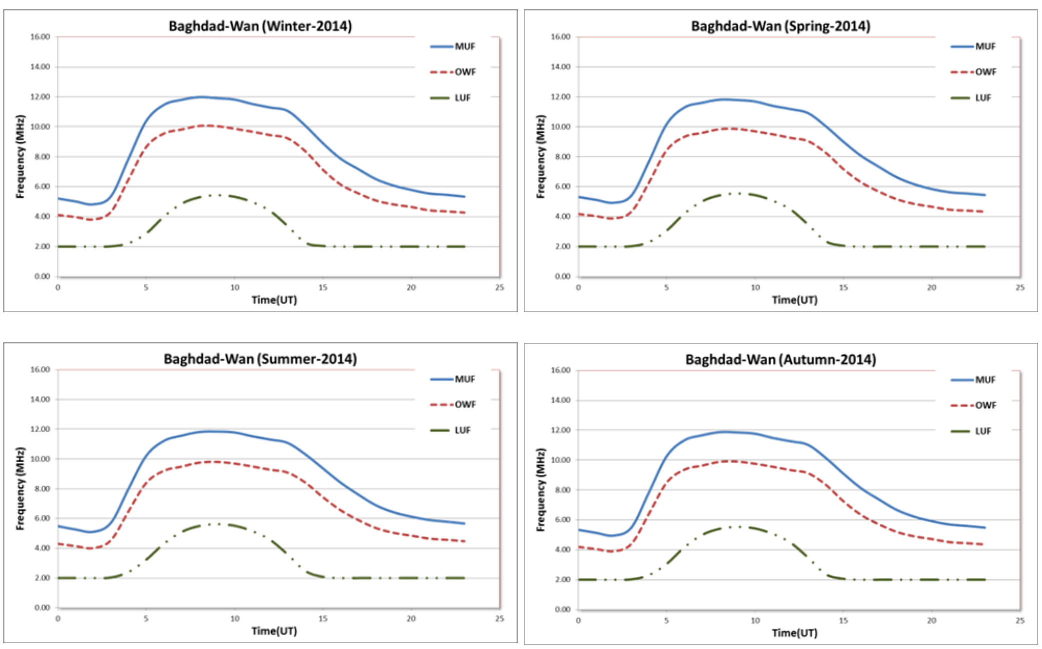


Figure 5:- Seasonal Variation of Ionospheric Parameters (MUF, LUF & OWF) for the year 2014.

The goal of this research is to get a mutual correlation between the ionospheric parameters. In order to get these correlated relationships, an investigational study of the generated datasets has been conducted for the seasonal time of the two tested years. Table (3) show samples of the correlation coefficients (a_o, a_1, a_2, a_3& a_4) and correlation parameter (R^2) over the Middle East zone of the seasonal time of the year 2009.

Table 3:- Samples of the correlation coefficients and correlation parameter over the Middle East zone of the seasonal time of the year 2009.

Baghdad- Wan (North Direction)						
Winter	a_0	a_1	a_2	a_3	a_4	R^2
MUF (OWF)	0.800	1.037	0.000	0.000	0.000	0.993
MUF (LUF)	- 360.160	466.770	- 217.070	43.951	-3.273	0.889
OWF (MUF)	- 0.737	0.958	0.000	0.000	0.000	0.993
OWF (LUF)	- 352.320	455.430	- 211.720	42.848	-3.190	0.870
LUF (MUF)	- 19.237	15.135	- 3.831	0.402	-0.014	0.964
LUF (OWF)	- 2.704	3.701	- 0.944	0.079	-0.000	0.929
Spring	a_0	a_1	a_2	a_3	a_4	R^2
MUF (OWF)	0.074	1.229	0.000	0.000	0.000	0.994
MUF (LUF)	- 174.910	215.840	- 92.327	17.037	-1.146	0.661
OWF (MUF)	- 0.031	0.808	0.000	0.000	0.000	0.994
OWF (LUF)	- 145.730	179.76	- 76.988	14.237	-0.961	0.633
LUF (MUF)	62.917	- 39.451	9.274	- 0.940	0.035	0.614
LUF (OWF)	37.370	- 26.194	6.942	- 0.785	0.032	0.522
Summer	a_0	a_1	a_2	a_3	a_4	R^2
MUF (OWF)	0.397	1.127	0.000	0.000	0.000	0.979
MUF (LUF)	- 27.856	36.309	- 13.482	2.147	-0.122	0.425
OWF (MUF)	- 0.225	0.868	0.000	0.000	0.000	0.979
OWF (LUF)	- 16.647	22.195	- 7.633	1.089	-0.052	0.351
LUF (MUF)	57.001	- 32.373	6.852	- 0.619	0.020	0.395
LUF (OWF)	- 148.220	126.550	- 39.327	5.325	-0.263	0.499
Autumn	a_0	a_1	a_2	a_3	a_4	R^2
MUF (OWF)	0.328	1.187	0.000	0.000	0.000	0.997
MUF (LUF)	- 265.170	336.060	- 151.370	29.704	-2.144	0.769
OWF (MUF)	- 0.262	0.839	0.000	0.000	0.000	0.997
OWF (LUF)	- 223.480	281.760	- 126.360	24.700	-1.777	0.766
LUF (MUF)	5.507	- 3.270	1.095	- 0.156	0.008	0.947
LUF (OWF)	15.406	- 13.079	4.629	- 0.704	0.038	0.879

The statistical analysis has been applied on the calculated datasets to assess the nature of correlation between these parameters. The results of the statistical analysis showed that the correlation between the ionospheric parameters could be expressed as a polynomial relationship, so the suggested mutual correlation equation between the studied parameters can be presented by the following equation:

$$Y = \sum_{i=0}^{n} a_i x^i \qquad \text{.........} (1)$$

$$Y = a_0 + a_1 x^1 + a_2 x^2 + a_3 x^3 + \cdots \qquad \text{.........} (2)$$

Figures (6) and (7) present illustrative charts of correlation between MUF and OWF parameters for all seasons of the years 2009 and 2014.

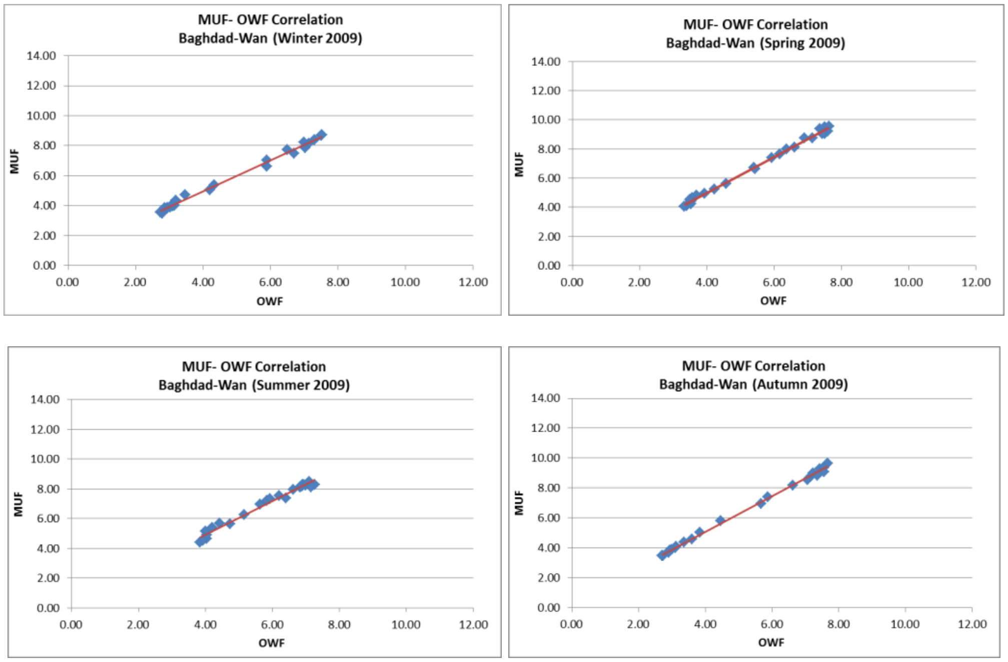


Figure 6:- Samples of correlation test between MUF and OWF parameters for seasonal time of year 2009.

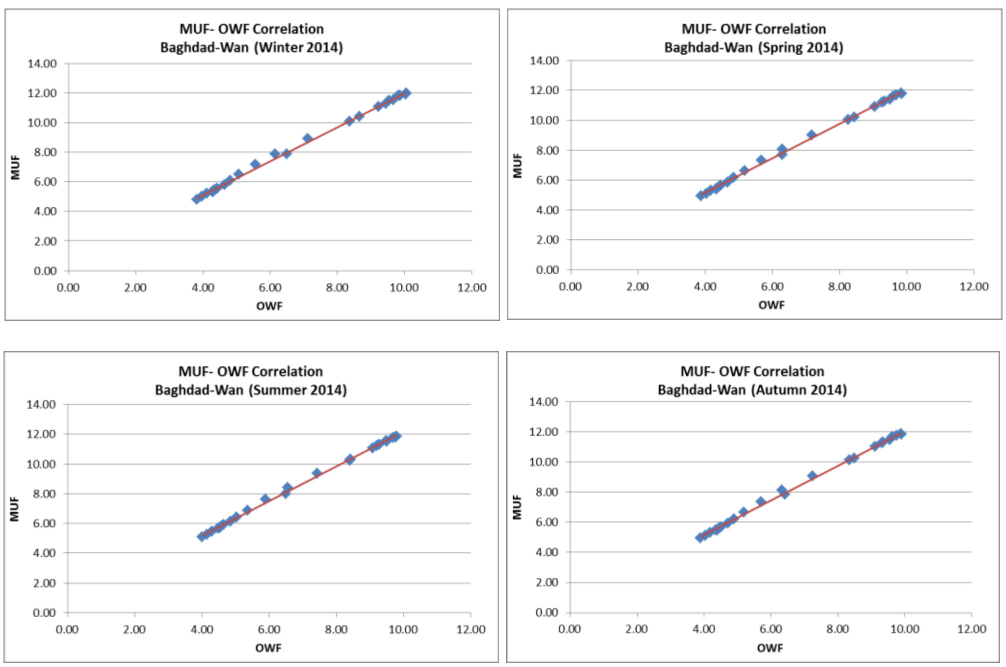


Figure 7:- Samples of the correlation between the MUF and OWF parameters for Seasonal times of the year 2014.

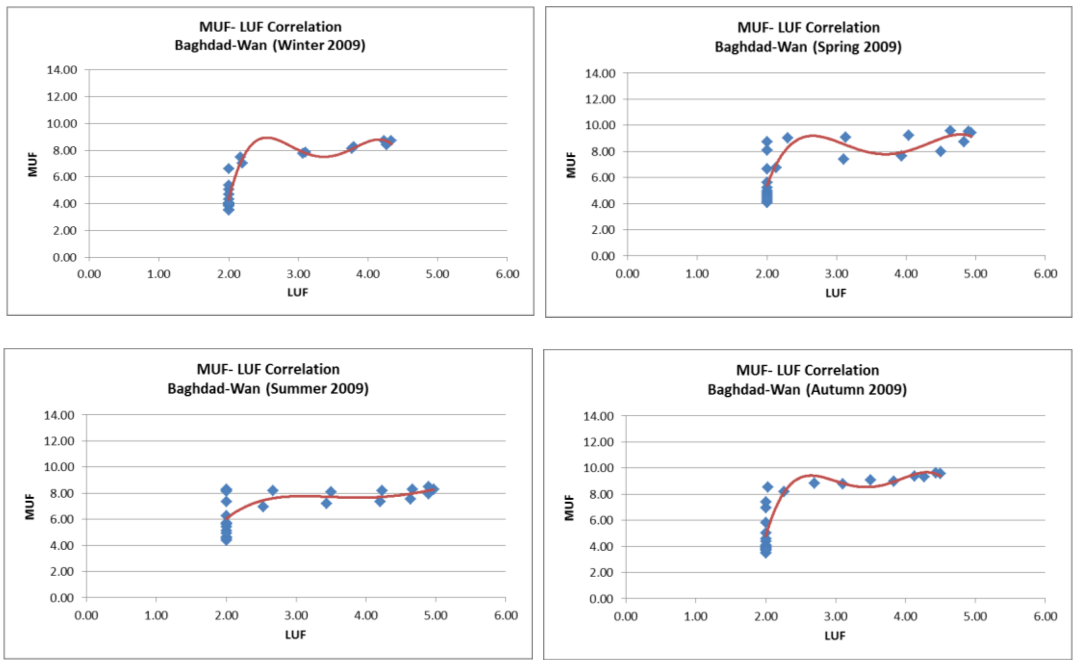
So, the suggested mutual correlation equations between (MUF, OWF and LUF), can be expressed by the following set of equations:

$$\mathrm{MUF} = \sum_{i=0}^{n} \mathrm{a_i}\,(LUF)^{i} \qquad \text{......... (3a)}$$

$$\mathrm{OWF} = \sum_{i=0}^{n} \mathrm{a_i}\,(LUF)^{i} \qquad \text{......... (3b)}$$

The values of MUF and OWF parameter have been correlated with LUF parameter for all distributed receiver locations over the adopted area for the seasonal time of the years 2009 and 2014. Figures (8) and (9)show samples of seasonal correlation between MUF and OWF with LUF parameters.

(MUF-LUF)



(OWF-LUF)

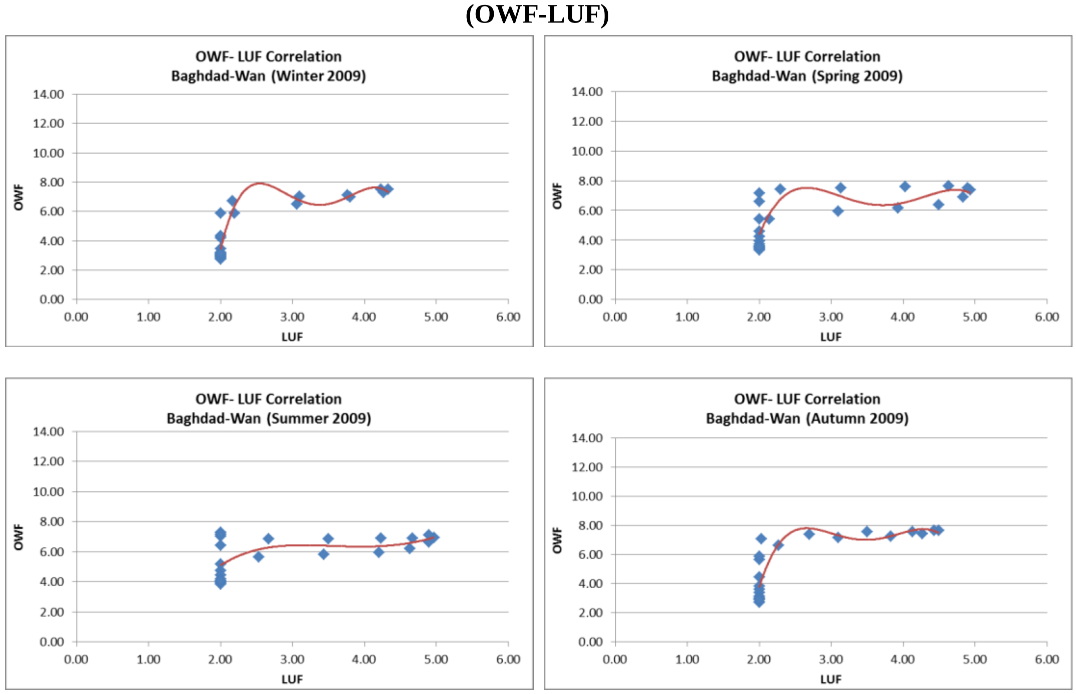
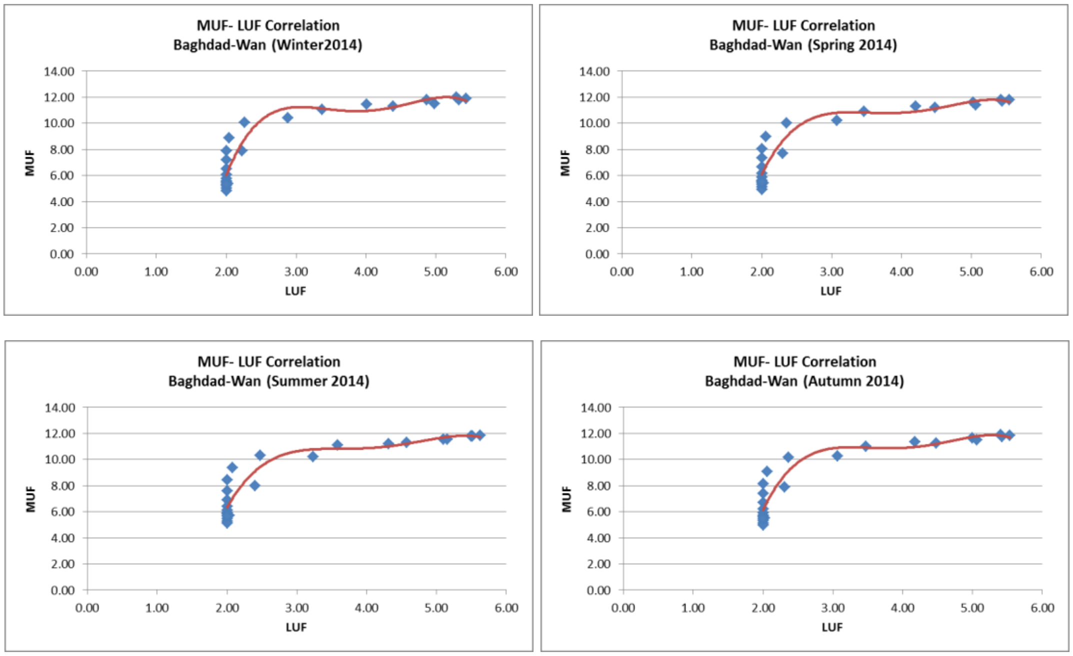


Figure 8:- Samples of the seasonal correlation between MUF, OWF with LUF parameters for the year 2009.

(MUF-LUF)



(OWF-LUF)

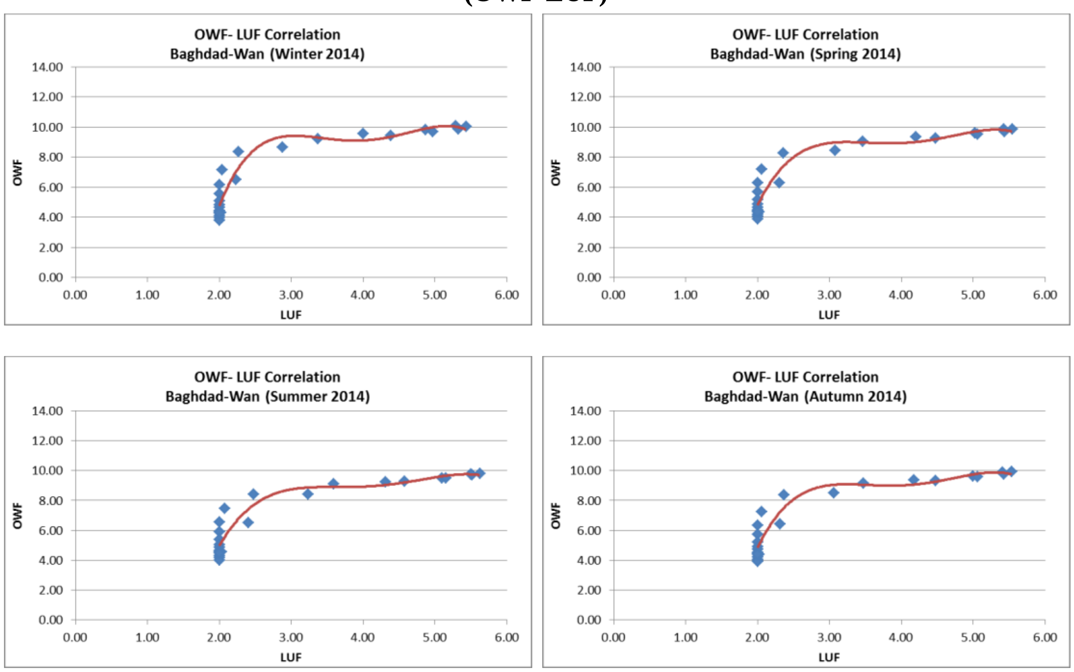


Figure 9:- Samples of seasonal correlation between the MUF, OWF with LUF parameters for year 2014

The comparison and mean square error (MSE) between the present value of MUF & OWF ionospheric parameter that have been calculated using the suggested mutual correlated equations with the predicted ionospheric values that have been generated using the international model (ASAPS) and theoretical values calculated depending on the international criterion equation (OWF = 0.85 x MUF) illustrate in table (4).

Table 4:- The Seasonal Theoretical, Predicted & Present value of the MUF, OWF parameters of adopted years.

Winter Time												
Baghdad- Wan (MUF- 2009)							Baghdad- Wan (MUF- 2014)					
UT	OWF	MUF					OWF	MUF				
		Predicted	Theoretical	Present	MSE			Predicted	Theoretical	Present	MSE	
					Theo.	Pred.					Theo.	Pred.
0	3.07	4.03	3.61	3.98	0.139	0.003	4.11	5.21	4.83	5.24	0.167	0.001
1	2.93	3.83	3.45	3.84	0.154	0.000	3.98	5.02	4.68	5.09	0.171	0.005
2	2.73	3.57	3.22	3.64	0.176	0.005	3.81	4.82	4.49	4.91	0.175	0.007
3	2.80	3.50	3.29	3.70	0.169	0.042	4.33	5.36	5.09	5.49	0.160	0.017
4	4.20	5.03	4.94	5.16	0.047	0.015	6.50	7.88	7.65	7.97	0.104	0.008
5	5.90	7.03	6.94	6.92	0.000	0.013	8.66	10.39	10.19	10.44	0.060	0.002
6	6.50	7.73	7.65	7.54	0.011	0.036	9.55	11.47	11.24	11.45	0.046	0.000
7	7.00	8.23	8.24	8.06	0.030	0.030	9.82	11.80	11.55	11.76	0.042	0.002
8	7.50	8.70	8.82	8.58	0.059	0.014	10.06	11.98	11.83	12.03	0.038	0.002
9	7.53	8.73	8.86	8.61	0.062	0.014	10.04	11.91	11.81	12.01	0.038	0.009
10	7.30	8.40	8.59	8.37	0.047	0.001	9.87	11.82	11.61	11.82	0.041	0.000
11	7.13	8.13	8.39	8.20	0.037	0.004	9.68	11.52	11.38	11.59	0.044	0.005
12	7.03	7.87	8.27	8.10	0.032	0.053	9.45	11.29	11.11	11.33	0.047	0.002
13	6.70	7.50	7.88	7.75	0.017	0.063	9.23	11.06	10.86	11.08	0.051	0.001
14	5.90	6.60	6.94	6.92	0.000	0.103	8.37	10.08	9.85	10.11	0.065	0.001
15	4.33	5.37	5.10	5.30	0.039	0.005	7.13	8.90	8.39	8.69	0.090	0.044
16	3.47	4.70	4.08	4.40	0.101	0.092	6.14	7.87	7.23	7.56	0.113	0.093
17	3.20	4.33	3.76	4.12	0.126	0.046	5.56	7.18	6.54	6.89	0.127	0.080
18	2.87	3.87	3.37	3.77	0.161	0.009	5.08	6.51	5.97	6.35	0.140	0.025
19	2.97	3.87	3.49	3.88	0.150	0.000	4.82	6.08	5.67	6.05	0.147	0.001
20	3.03	3.90	3.57	3.95	0.143	0.002	4.65	5.78	5.47	5.86	0.151	0.005
21	3.10	3.97	3.65	4.02	0.136	0.002	4.43	5.55	5.21	5.60	0.158	0.003
22	3.17	4.00	3.73	4.08	0.129	0.007	4.35	5.46	5.12	5.52	0.160	0.004
23	3.13	4.03	3.69	4.05	0.133	0.000	4.28	5.34	5.03	5.43	0.162	0.009
				Average MSE	**0.087**	**0.023**				**Average MSE**	**0.104**	**0.014**

Winter Time												
Baghdad- Wan (OWF- 2009)							Baghdad- Wan (OWF- 2014)					
UT	MUF	OWF					MUF	OWF				
		Predicted	Theoretical	Present	MSE			Predicted	Theoretical	Present	MSE	
					Theo.	Pred.					Theo.	Pred.
0	4.03	3.07	3.43	3.13	0.091	0.004	5.21	4.11	4.43	4.09	0.118	0.000
1	3.83	2.93	3.26	2.94	0.104	0.000	5.02	3.98	4.26	3.92	0.121	0.003
2	3.57	2.73	3.03	2.68	0.124	0.003	4.82	3.81	4.10	3.75	0.124	0.005
3	3.50	2.80	2.98	2.62	0.129	0.034	5.36	4.33	4.55	4.22	0.115	0.012
4	5.03	4.20	4.28	4.09	0.037	0.013	7.88	6.50	6.70	6.42	0.076	0.006
5	7.03	5.90	5.98	6.00	0.001	0.010	10.39	8.66	8.83	8.62	0.046	0.002
6	7.73	6.50	6.57	6.67	0.010	0.030	11.47	9.55	9.75	9.56	0.035	0.000
7	8.23	7.00	7.00	7.15	0.023	0.023	11.80	9.82	10.03	9.85	0.032	0.001
8	8.70	7.50	7.40	7.60	0.041	0.010	11.98	10.06	10.19	10.01	0.030	0.002
9	8.73	7.53	7.42	7.63	0.043	0.009	11.91	10.04	10.13	9.95	0.031	0.008
10	8.40	7.30	7.14	7.31	0.029	0.000	11.82	9.87	10.04	9.87	0.032	0.000
11	8.13	7.13	6.91	7.06	0.020	0.006	11.52	9.68	9.79	9.61	0.034	0.004
12	7.87	7.03	6.69	6.80	0.013	0.055	11.29	9.45	9.60	9.40	0.037	0.002
13	7.50	6.70	6.38	6.45	0.005	0.063	11.06	9.23	9.40	9.20	0.039	0.001
14	6.60	5.90	5.61	5.59	0.001	0.099	10.08	8.37	8.57	8.34	0.049	0.001
15	5.37	4.33	4.56	4.40	0.025	0.005	8.90	7.13	7.57	7.31	0.063	0.034
16	4.70	3.47	4.00	3.77	0.053	0.089	7.87	6.14	6.69	6.41	0.077	0.072
17	4.33	3.20	3.68	3.41	0.072	0.046	7.18	5.56	6.10	5.80	0.086	0.062
18	3.87	2.87	3.29	2.97	0.102	0.010	6.51	5.08	5.53	5.22	0.097	0.020
19	3.87	2.97	3.29	2.97	0.102	0.000	6.08	4.82	5.16	4.84	0.103	0.001
20	3.90	3.03	3.32	3.00	0.100	0.001	5.78	4.65	4.92	4.59	0.108	0.004
21	3.97	3.10	3.37	3.06	0.095	0.001	5.55	4.43	4.72	4.38	0.112	0.002
22	4.00	3.17	3.40	3.10	0.093	0.005	5.46	4.35	4.64	4.30	0.114	0.003
23	4.03	3.13	3.43	3.13	0.091	0.000	5.34	4.28	4.54	4.20	0.116	0.006
				Average MSE	**0.058**	**0.022**				**Average MSE**	**0.075**	**0.010**

Summer Time												
Baghdad- Wan (OWF- 2009)							Baghdad- Wan (OWF- 2014)					
UT	MUF	OWF					MUF	OWF				
		Predicted	Theoretical	Present	MSE			Predicted	Theoretical	Present	MSE	
					Theo.	Pred.					Theo.	Pred.
0	4.63	4.03	3.94	3.80	0.020	0.056	5.49	4.30	4.66	4.27	0.153	0.001
1	4.40	3.83	3.74	3.59	0.021	0.057	5.26	4.14	4.47	4.08	0.154	0.004
2	4.53	3.93	3.85	3.71	0.020	0.050	5.11	4.01	4.34	3.95	0.155	0.005
3	5.63	4.73	4.79	4.67	0.015	0.005	5.71	4.54	4.86	4.47	0.151	0.006
4	6.97	5.63	5.92	5.82	0.010	0.036	8.01	6.50	6.81	6.44	0.137	0.004
5	7.20	5.83	6.12	6.03	0.009	0.037	10.22	8.40	8.69	8.33	0.124	0.004
6	7.33	5.93	6.23	6.14	0.008	0.043	11.22	9.21	9.54	9.20	0.119	0.000
7	7.53	6.20	6.40	6.32	0.008	0.013	11.57	9.49	9.84	9.49	0.117	0.000
8	7.93	6.63	6.74	6.66	0.007	0.001	11.81	9.76	10.04	9.70	0.115	0.003
9	8.30	6.93	7.06	6.98	0.005	0.002	11.85	9.81	10.07	9.73	0.115	0.006
10	8.47	7.10	7.20	7.13	0.005	0.001	11.79	9.70	10.02	9.68	0.116	0.000
11	8.30	6.90	7.06	6.98	0.005	0.007	11.53	9.50	9.80	9.46	0.117	0.002
12	8.20	6.90	6.97	6.89	0.006	0.000	11.31	9.28	9.62	9.27	0.118	0.000
13	8.10	6.83	6.89	6.81	0.006	0.001	11.08	9.09	9.42	9.07	0.120	0.000
14	8.17	6.87	6.94	6.87	0.006	0.000	10.32	8.42	8.77	8.42	0.124	0.000
15	8.23	7.00	7.00	6.92	0.006	0.006	9.37	7.43	7.96	7.60	0.129	0.029
16	8.30	7.27	7.06	6.98	0.005	0.082	8.41	6.56	7.15	6.78	0.135	0.051
17	8.13	7.17	6.91	6.84	0.006	0.109	7.61	5.90	6.47	6.10	0.140	0.039
18	7.37	6.40	6.26	6.17	0.008	0.053	6.89	5.36	5.85	5.47	0.144	0.013
19	6.27	5.17	5.33	5.22	0.012	0.002	6.42	5.04	5.46	5.08	0.147	0.001
20	5.70	4.43	4.85	4.72	0.015	0.084	6.13	4.85	5.21	4.82	0.149	0.001
21	5.40	4.20	4.59	4.46	0.016	0.069	5.91	4.66	5.02	4.63	0.150	0.001
22	5.13	4.00	4.36	4.23	0.017	0.054	5.79	4.57	4.92	4.54	0.151	0.001
23	4.90	4.03	4.17	4.03	0.019	0.000	5.66	4.48	4.81	4.42	0.152	0.003
				Average MSE	**0.011**	**0.032**				Average MSE	**0.135**	**0.007**

Summer Time												
Baghdad- Wan (MUF- 2009)							Baghdad- Wan (MUF- 2014)					
UT	OWF	MUF					OWF	MUF				
		Predicted	Theoretical	Present	MSE			Predicted	Theoretical	Present	MSE	
					Theo.	Pred.					Theo.	Pred.
0	4.03	4.63	4.75	4.95	0.040	0.098	4.30	5.49	5.06	5.53	0.216	0.002
1	3.83	4.40	4.51	4.72	0.044	0.103	4.14	5.26	4.88	5.34	0.217	0.006
2	3.93	4.53	4.63	4.83	0.042	0.090	4.01	5.11	4.72	5.19	0.219	0.007
3	4.73	5.63	5.57	5.74	0.028	0.010	4.54	5.71	5.35	5.81	0.213	0.009
4	5.63	6.97	6.63	6.75	0.015	0.047	6.50	8.01	7.65	8.08	0.190	0.005
5	5.83	7.20	6.86	6.98	0.013	0.050	8.40	10.22	9.88	10.29	0.169	0.005
6	5.93	7.33	6.98	7.09	0.012	0.060	9.21	11.22	10.84	11.24	0.161	0.000
7	6.20	7.53	7.29	7.39	0.009	0.021	9.49	11.57	11.16	11.56	0.158	0.000
8	6.63	7.93	7.80	7.88	0.006	0.003	9.76	11.81	11.48	11.88	0.155	0.004
9	6.93	8.30	8.16	8.22	0.004	0.007	9.81	11.85	11.54	11.93	0.155	0.007
10	7.10	8.47	8.35	8.40	0.003	0.004	9.70	11.79	11.41	11.80	0.156	0.000
11	6.90	8.30	8.12	8.18	0.004	0.015	9.50	11.53	11.18	11.57	0.158	0.002
12	6.90	8.20	8.12	8.18	0.004	0.000	9.28	11.31	10.92	11.32	0.160	0.000
13	6.83	8.10	8.04	8.10	0.004	0.000	9.09	11.08	10.69	11.09	0.162	0.000
14	6.87	8.17	8.08	8.14	0.004	0.001	8.42	10.32	9.90	10.31	0.169	0.000
15	7.00	8.23	8.24	8.29	0.003	0.003	7.43	9.37	8.74	9.17	0.180	0.040
16	7.27	8.30	8.55	8.59	0.002	0.086	6.56	8.41	7.71	8.15	0.189	0.069
17	7.17	8.13	8.43	8.48	0.002	0.120	5.90	7.61	6.94	7.38	0.197	0.052
18	6.40	7.37	7.53	7.62	0.007	0.062	5.36	6.89	6.31	6.76	0.203	0.017
19	5.17	6.27	6.08	6.22	0.021	0.002	5.04	6.42	5.93	6.39	0.207	0.001
20	4.43	5.70	5.22	5.40	0.033	0.092	4.85	6.13	5.71	6.16	0.209	0.001
21	4.20	5.40	4.94	5.13	0.037	0.071	4.66	5.91	5.48	5.94	0.211	0.001
22	4.00	5.13	4.71	4.91	0.041	0.051	4.57	5.79	5.38	5.84	0.212	0.002
23	4.03	4.90	4.75	4.95	0.040	0.002	4.48	5.66	5.27	5.73	0.214	0.004
				Average MSE	**0.017**	**0.041**				Average MSE	**0.187**	**0.010**

Conclusion:-

1. For the determination of bearing parameter, the first method showed more accurate values than the second one.
2. The behavior of the ionospheric parameters for the seasonal times showed a variation in the values of these parameters for the two studied years, especially for the summer time, which may due to the impact of the solar activity (sunspot number) on the structure of the ionosphere layer (electron density).
3. The mutual correlation between MUF & OWF is simple and can be represented by a simple mathematical relationship "linear regression equation".
4. The values calculated from the suggested mutual correlation equation gave a good fit with the other values generated from the international model and criterion.
5. The correlation between MUF and OWF parameters achieved a percentage mutuality of 99% (correlated coefficient) that gave better correlated mutuality than the international recommended criterion (85%).
6. The correlated relationship between (MUF & LUF), (OWF & LUF) is a polynomial which represented by a fourth order polynomial equation (Quartic Polynomial Equation).
7. The datasets which have been generated from the suggested mutual correlation equation was closer to the values calculated from the international model than the values calculated depending on the international recommended criterion.

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