Effect of Upper Atmosphere on Terrestrial and Earth Communications : Near Earth Space Dimension in Turkey Since 1960's Concerning Ionospheric Radio Propagation

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Abstract : In this paper the scientific activities related to the effects of the Near Earth Space on Ionospheric Radio Propagation will be briefly introduced for the last forty years in Turkey. In addition, there will be some typical results presented as illustration of the relevant work.

1. Introduction

I would like to base my talk on two fundamental aspects which are inseparable :

- i) Space weather
- ii) radiowave propagation

Then, some original results will be presented on the space weather effect on ionospheric critical frequencies.

1.1. Space Weather

There are more than one definitions of the space weather. As an example, here is the one given by the US National Space Weather Plan. "Condition on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health."

Quating from Siscoe (2000), "To be able to talk about the network of space-vulnerable, technological entities upon which humankind is becoming increasingly dependent, I suggest referring to it as the cyberelectrosphere. The cyberelectrosphere is defined as the global totality of all space-vulnerable, electrically enabled technological systems. If we could see the network comprised of this totality by itself –see the satellite links, the cable links, the navigation and positioning links, the electric power grids, and the radio links – the image would resemble a picture out of Grey's Anatomy showing the central nervous system or the circulation system. Here the sensory, information and energy transfer network does not belong to the human body to an abstarct, interconnected global entity – the cyberelectrosphere.

Figure 1 attempts to show how the cyberelectrosphere emerges from an interaction between three subjects : society, science and space weather. Before science, the overlap of society and space weather in the form of lowlatitude auroras that accompany space storms gave rise to omens and wonders. The overlap of space weather and science has given rise to the fields of space physics and aeronomy. The overlap of science and societyhas engendered modern technological society, those components of which that are vulnerable to space-weather disturbances form the cyberelectrosphere at the center of the triquetra."



Figure 1. A triquetra illustrating how the intersection of society, science, and space weather gives rise to the cyberelectrosphere (Siscoe, G., 2000).

1.2. Radiocommunications and the Radio Spectrum (Radicella, 1995)

The radio spectrum is the natural resource used, but not consumed, in radiocommunications and ranges from very low frequencies (3-30 KHz) to optical frequencies (300-3000 THz).

Radio spectrum utilization and management involves technical factors together with economic, political and sociological aspects that make necessary the establishment of international agreements and national regulations. The Radiocommunication Sector of the International Telecommunication Union is the body in charge of ensuring the rational, equitable, efficient and economical use of radio spectrum by all radiocommunication services.

Founded in 1865, it became a specialized agency of the United Nations in 1947, the International Telecommunication Union (ITU) provides an international forum for discussion in which its 189 Member States and some 690 Sector Members and associates can collaborate for the improvement and rational use of telecommunications worldwide.

The mission of the ITU-R lies within the broader framework of the purposes of the ITU, as defined in Article 1 of the ITU Constitution and is, in particular, to "maintain and extend international cooperation among all the Member States of the Union for the improvement and rational use of telecommunications of all kinds".

It represents one of the major growth industries with a value of approximately 17 US \$ billion per year and a subscribers annual increase of 45%.

By the beginning of the 21st century the Commission of the European Communities (CEC) had envisaged that 50% of the total teletraffic to be radio based and an ambitious research program was started under the Research and Advanced Communications for Europe (RACE) program to study the creation of a third generation mobile system.

By the beginning of the 21st century Personal Communications Mobile Satellite Systems, for example, like MOTOROLA IRIDIUM, INMARSAT PROJECT 21 and TRW ODYSSEY have been planned to be operational for global scale communications and on them R-T-D have been continuing.

Reasons for a Renewed Interest in High-Frequency Radio Applications to Telecommunication Systems as summarized by Radicella (1995) can be summarized as :

- The availability of enhanced digital signal and data processing chips and systems that permit the development of high performance communication systems, far better than former HF systems.
- The need for low cost systems for non heavy traffic telecommunication links in the absence of reliable alternative network systems, like in developing countries.
- The need for reliable backup systems for emergency uses, like telecommunication requirements after natural disasters.
- The need for multimedia transmission networks to enhance the probability of successful reception of military or national security information.

1.2. Some Relevant Examples

Radicella, in his 1995 paper gave the "Wide Band Spread Spectrum" as an example of new technology use for HF communications. In the same paper Radicella gave another example of HF Radio Engineering solution for low cost low traffic communications as "Near-Vertical Incidence Sky-Wave (NVIS) Antenna Techniques".

It took less than ten years for them to become operational. These topics were among the themes of the FP6, 2nd Call of proposals in 2004. Summarising,

New Technology Use of HF Communications : Wideband Spread-Spectrum

Wideband spread-spectrum technology has several advantages for communication systems :

- Low-probability-of-intercept communications
- Interference rejection

• Simultaneus operation of various transmitters in the same frequency band

Modern digital technology with real time signal processing permits automatic compensation for ionospheric distorsion when wideband spread-spectrum is used.

HF Radio Engineering Solution for Low Cost Low Traffic Communications : Near-Vertical Incidence Sky-Wave (NVIS) Antenna Techniques

- NVIS Antenna techniques allow HF use for long and short distance communications (including the skip distance), regardless of ground conductivity conditions.
- These techniques and an adequate choice of operating frequencies and equipment permit the use of HF radio systems for rural communications networks like environmental condition monitoring.

1.3. Near Earth Space Activities in Turkey

Some Near Earth Space activities in Turkey since 1970 which are relevant to ionospheric radiowave propagation.

- i) By using the Ariel 3 and Ariel 4 satellite electron density, VLF data the morphology of the upper atmosphere at about 550 km was investigated widely.
- ii) The Mid-Latitude Electron Density Trough was shown to be the ionospheric projection of the magnetospheric plasmapause by using Ariel 3, Ariel 4, OGO 4, ISEE 1, KYOKKO satellite data. Some modeling work of the Trough was performed in parallel.
- iii) The possible influence of the Interplanetary Magnetic Field (IMF) Bz polarity reversals on ionospheric foF2 data in relation to quantification of the ionospheric variability was investigated.
- iv) The total electron content (TEC) over Ankara longitudes was computed by using the ATS 6 satellite Faraday rotation signals.
- v) An High Frequency (HF) Fading Experiment was conducted between United Kingdom and Turkey.
- vi) As part of the COST 238: PRIME Action the Polish make KOS Vertical Ionosonde was deployed at the Kandilli Observatory of the Boğaziçi University
- vii) Within the COST 251: IITS Action data driven modeling approach was introduced and neural network based models were constructed for forcasting foF2 one to twentyfour hours in advance for single stations and one hour in advance for multi stations. Neural network based models were also constructed to forecast foF2 one hour in advance during IMF Bz polarity reversals and to model the effect of Mid-Latitude Ionospheric Trough on foF2 values.
- viii) An HF propagation experiment in Ankara and Elazığ was conducted during the last total solar eclipse of the century, 11 August 1999.
- ix) The European Science Foundation (ESF) Network on Earth Weather and Space Weather was one of the other European Union (EU) activity in the Near Earth Space discipline that Turkish scientists took part. It is expected that there will be a second phase of the activity.
- x) Solar, geomagnetic field, seismic and geophysical observations have been conducted at the Kandilli Observatory of the Boğaziçi University.
- xi) An HF channel characterization project supported by the Turkish State Planning Organization is being conducted at the Middle East Technical University in Ankara. As part of this activity, an HF transmission experiment will be conducted by setting up an International Telecommunication Union (ITU)-Compliant HF Field Strength Monitoring Terminal. The work will be carried out in collaboration with International Telecommunication Union, Commission R. The same station will be set up at the Firat University in Elazığ, Turkey.
- xii) A NATO-RTO project on the Surface Boundary Layer Refractive Index Measurements in Greece, Turkey and UK Relevant to Optical and Microwave Frequencies in Aerospace Operations.
- xiii) At the Department of Meteorology and the Department of Physics of a few Turkish universities, some work on the Earth's magnetosheath, magnetotail, solar wind-magnetosphere-ionosphere coupling, magnetohydrodynamics, plasma physics research related to Space Physics have been conducted.
- xiv) There are a few electric and electronic engineering departments where theoretical electromagnetics and propagation research have been conducted.

2. Results

In this section the results of some typical and original research activities conducted in Turkey will be summarized.

2.1. HF Relative Signal Strength Measurement Between Ankara and Elazığ

The objective of the experiment between Ankara (40°N, 33°E,) and Elazığ (38°N, 39°E,) was to observe the relative variations in the signal strength during the 11 August 1999 total solar eclipse. Table 1 shows the times relevant to the 11 August 1999 total solar eclipse.

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	Beginning of Partial	Maximum	End of Partial	
	Eclipse	96.7 %	Eclipse	
Ankara	10:58:13	12:24:58	13:45:01	
	Beginning of Partial	Beginning of	End of Total	End of Partial
	Eclipse	Total Eclipse	Eclipse	Eclipse
Elazig	11:12:23	12:36:14	12:38:18	13:2-54:02

 Table 2.1. Times (UT) of partial and total (or maximum) eclipse in Elazığ and Ankara during the August 11, 1999 total solar eclipse.

The receiver and transmitter used were both Harris RF 3200 type 150W HF transceivers. The transmitter was located in Ankara while the receiver was located in Elazığ. The transmitting antenna was a yagi type antenna and could be directed in any direction with remote control. The receiving antenna was a Rohde&Schwartz HE 011 calibrated active monopole. The data were recorded by laptop personal computer running software specific to the prolab multimeter, which gave an RS 232 serial output to the computer. A block diagram of the experiment set up is shown in Figure 2. The radio was tested and an appropriate point in the circuitry of the radio was found from which it was possible to obtain a measure of the relative strength of the received signal. A suitable point which provides a DC voltage between 0.7 and 6.5 V representing the relative signal strength in the range of 0 to -120dBm was located on the receiver electronic card.



Figure 2. Setup of equipment in HF relative signal strength experiment.

A link was made at 18.111 MHz and a 12000 seconds recording of data was made. The results are displayed in Figure 3. The time was synchronized with universal time (UT) through an atomic clock time server on the internet. When the running mean of the recorded data shown in Figure 4 is taken in order to eliminate the oscillations observed on Figure 3, a clear decrease of strength during the eclipse, became very obvious. The HF relative field strength reached a minimum near the times at which the total eclipse occurred at Elazığ and it began to rise to a value near the value observed at the beginning of the eclipse. Similarly, Jakowski et al. (1999) reported that TEC level decreased considerably on 11 August 1999 reacting abruptly the switching off of the solar radiation. The results presented in Figure 4 indicates that the relative signal strength decreases due to the total solar eclipse of 11 August 1999. The opposite type of variation would have been expected since the rate of absorption in the ionosphere decreases due to decrease of photo electrons in the shadow of the moon. It is believed that since the HF radiowave frequency of 18.111MHz is near to the natural ionospheric critical frequency, the probable thinning of the ionosphere caused the part of the HF wave to be transmitted into space above the ionosphere instead of being reflected back to the Earth.



Figure 3. Plot of relative signal strengths measured during the total solar eclipse.



Figure 4. Plot of running mean of relative signal strengths measured during the total solar eclipse.

2.2. Modelling : Magnetospheric and Ionospheric Coupling

Natural processes such as the near-Earth space are highly complex, nonlinear and time varying. Therefore, mathematical modeling is usually very difficult or impossible. Data-driven approaches such as the Neural Network (NN) based modelling are shown to be promising for such cases. The only basic requirement is the availability of representative data.

2.2.1. The Temporal and Spatial Forecasting of Ionospheric Critical Frequency foF2 Values up to 24 Hours in Advance (Tulunay et al., 2000)

Forecasting of foF2 is important for the telecommunication system planner, users and other groups of interests. Input data for training, test and validation sets are from the years 1979, 1968 and 1990 respectively, for the same months. RMS errors related to this model for three ionospheric stations are shown in Table 2.1.

Table 2.1. KWS enors for the forecast of for 2.1 fi. in advance in Wi					
Station\Month	Sept. 1990	Dec. 1990			
Poiters	0.12566	0.12304			
Slough	0.13319	0.11353			
Uppsala	0.15652	0 13719			

Table 2.1. RMS errors for the forecast of foF2 1 h. in advance in MHz.

The Influence of the Mid Latitude electron density Trough on High Frequency (HF) communication is discussed in other studies (Tulunay et al. 2001; Tulunay et al. 2000).

2.2.2. Forecasting GPS TEC During High Solar Activity (Tulunay et al., 2002)

Total Electron Content (TEC) data evaluated from GPS between measurements from 2000 to 2001 at Chilbolton (51.8 N, 1.26 W) receiving station for April and May are used for the training, test and validation the METUNN. An additional validation has been performed on an independent validation data set by using the TEC values at Halisham (50.9 N, 0.3 E) receiving station for selected months in 2002. Errors and forecast of TEC one-hour ahead results are shown in Table 2.2 and Figure 5, respectively.

Table 2.2. Error Table

RMS Error ($el/sqm * 10^{16}$)	1.87544
Normalized error	0.07259
Absolute error (el/sqm $* 10^{16}$)	1.22433
Cross Correlation Coefficient	0.98495



Figure 5. Observed (red), 1h ahead forecast (blue), monthly median (black) of TEC for 18-22 April 2002.

2.2.3. The Trough Based Neural Network Model of the foF2 Values (Tulunay et al., 2000)

HF radio communication requires forecasting the ionospheric critical frequencies, foF2. Probable influence of the mid latitude electron density Trough at the altitudes that the foF2 values measured was sought by Tulunay et al. 2000. A data driven (based) modelling approach yielded a neural network model which forecasted the foF2 values one hour in advance for a single station with the assumption that the Trough coincides at the ionospheric heights of the station. As typical examples the results of the analysis for Slough will be presented here.

Figure 6 (b) shows the observed and one hour ahead forecast foF2 values during day time between 9 and 15 hour local time. The 3h-Kp values were 3 and 4 during the period of interest.

The properly constructed and trained NN based system can learn the shape of any inherent non-linear variations. Figures 6 a and b show that this ability of NN based system was employed successfully. In order to evaluate the performance of the NN based model in terms of the closeness of forecast values to the observed and ad forecast foF2 values were computed. For example, the absolute error dropped from being 0.62 MHz to 0.50MHz when the probable influence of the trough inherently had been included in the analysis (Tulunay et al., 2000).



Figure 6. Observed (blue, dotted) and 1 h ahead forecast (red, solid) foF2 values versus the order of data for the Slough station during January-May 1982 in the expanded horizontal scale were shown for (a) 21 and 03h LT; 3h-Kp values 2 and 3; (b) 9 and 15h LT; 3h-Kp values 3 and 4.

Conclusion

The Near Earth Space activities in Turkey in the last fourty five years constitute mainly the sporadic research activities. However, the recent participation in national, and international projects have been contributing towards a more systematic research activity with more definite objectives since 1990.

With some recent work conducted it is demonstrated that neural network based modelling of a complex nonlinear process is very promising on the effects of upper atmosphere on terrestrial and Earth communication in particular ionospheric radio propagation.

Some relevant references of the published work at the international journals by the Turkish authors is presented at the end of this text (Appendix-1) since 1990.

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APPENDIX-1

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AIAA; European Geoscience Union (EGU), COSPAR, URSI, Türk, Avrupa, Amerikan Fizik Dernekleri; Avrupa ve Amerikan Jeofizik Birlikleri, Türk Isı Bilimi ve Tekniği Derneği, Türkiye Kalite Derneği (KAL-DER) üyesi olduğu kuruluşlardır.

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