# Investigation of Atmospheric Gases Attenuation in UAE

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***Abstract*** **- This paper presents the first results of atmospheric gases attenuation statistics in the UAE (United Arab Emirates) for a period of 14 years (1990-2003). Six sites have been considered for this study using meteorological surface data (Abu Dhabi, Dubai, Sharjah, Al-Ain, Ras Al-Khaimah and Al-Fujairah). Upper air (radiosondes) data were available at one site only, Abu Dhabi airport, which has been considered for gases attenuation calculations using Line-by-Line method. Hourly averages of slant path gases attenuation are obtained. Cumulative distributions are provided as well.**

***Index terms*** **– Gases, Attenuation, Propagation, Atmospheric measurements, Millimeter wave radio propagation meteorological factors.**

## I. Introduction

Propagation losses occur when electromagnetic waves traveling through the atmosphere are absorbed by molecules of oxygen, water vapor and other gaseous atmospheric constituents. Intensive work has been done during the last few decades to investigate the slant path attenuation at different parts of the world. References [1, 2, 3, 4, 5, and 6] are just an example of these studies. However, still in the Arabian Gulf region the available data need to be analyzed to provide precise values of signal path attenuation using real local measurements. These results are quite interested for the communication community.

In this study, two methods proposed by Salonen [7 and 8] to estimate oxygen and water vapor attenuation have been considered, in addition to both Approximation and Line-by-line calculations methods described in the ITU Recommendation 676 [9] are used.

## II. Available Meteorological Data

This study has been conducted in the UAE utilizing reliable meteorological data at six locations, see Table-I.

Surface data are taken hourly, while vertical profiles of meteorological parameters are taken using radiosondes, two times daily, at 0 Hours and 12 Hours GMT, at fixed pressure levels.

TABLE I
Location of Meteorological Stations

| Site | Latitude | Longitude | Altitude (m) |
|---|---|---|---|
| **Abu Dhabi** | 24.52ºN | 54.98ºE | 27 |
| **Dubai** | 25.26ºN | 55.33ºE | 8 |
| **Sharjah** | 25.37ºN | 55.41ºE | 33.7 |
| **Al-Ain** | 24.33ºN | 58.74ºE | 262 |
| **Ras Al-Khaimah** | 25.79ºN | 55.94ºE | 31 |
| **Al-Fujairah** | 25.13ºN | 56.34ºE | 24.3 |

Data are analyzed for all sites for the 14 years period, from January 1st, 1990 to December 31st, 2003, except two sites, Al-Ain for 9 years, from 1995 to 2003, and Al-Fujairah for 8 years, from 1996 to 2003, where the data set was available for these periods only.

## III. Analysis And Results

### *A. Hourly Averaging Distributions*

**Abu Dhabi site**: Hourly distributions for oxygen (dry component) and water vapor (wet component) and their summation for this site are shown in Figs. 1 and 2. Calculations have been done using fixed elevation angle of $40^o$ and frequency of 50 GHz. The three methods, Approximation, Line-by-Line, and Salonen, have been used since radiosondes data set is available for this site only. Results are shown in universal time, where local time is leading by 4 hours. In February the water vapor attenuation value in both Salonen and Approximation methods is almost constant and doesn't exceed 0.6 dB. For dry air, the attenuation value oscillates between 1.8 and 2.1 dB for Approximation method, and it has almost a constant value of 2.1 dB for Salonen method. Since the variability is low for both wet and dry components, then as a consequence, the variability is too low for the total attenuation for both Approximation and Salonen methods. Also it can be seen that the attenuation values at daily hours is less than the attenuation at night hours. In August, the water vapor attenuation has high variability compared with February, especially in the day time. This may attributed to the decrease of relative humidity value during day time and therefore the attenuation due to wet component will be low. The dry air attenuation value is higher than wet attenuation with lower variability. The total attenuation oscillates between 2.25 dB and 2.75 dB for Approximation method and between 2.75 dB and 3.25 dB for Salonen. The attenuation decreases from 3 Hours to 15 Hours. The total attenuation has similar tendency of wet component attenuation. It is inversely proportional with the value of temperature measurements.

The two red colored points indicate the attenuation values calculated using Line-by-Line method. Attenuation of 2.3 dB in February and 2.4 dB in August. Referring to Fig. 2, the percentage of error can be calculated using the Line-by-Line method as a reference. The error is 8% for Approximation method and 20% for Salonen method. Therefore, it is clear that Salonen method gives poor results compared to Approximation method.

**All Sites, February, Approximation method**: Referring to Fig. 3, it can be seen that the coastal cities that located nearby the Arabian Gulf (i.e. Abu-Dhabi, Dubai, Sharjah and Ras Al-Khaimah) have attenuation values close to each other for all the day. Al-Ain city has the lowest values. It is clear that Al-Fujairah has the lowest variability and the highest attenuation values. The range of attenuation values oscillates between 2.1 dB and 2.45 dB. Its value decreases during daily hours.

**All Sites, August, Approximation method**: Referring to Fig. 4, in August, the curves of total attenuation are spread out and the variations are higher compared with February. Abu-Dhabi has the highest variation. Al-Ain has the lowest attenuation values and this may be attributed to its dry climate during summer time. Al-Fujairah has the lowest variation and the highest values of total attenuation. Other coastal sites have also significant variability, but with lower values. Again in general, attenuation values are low during day time, from 5 Hours to 15 Hours, where temperatures are getting higher and relative humidity is getting lower which decreases the total attenuation.

**All Sites, February and August, Salonen method**: Referring to Figs. 5 and 6, the behavior is the same as the Approximation method with difference value of 0.3 dB for Al-Ain site and 0.2 dB for other sites in February. For August the difference of attenuation values is about 0.6 dB for Al-Fujairah site and about 0.4 dB for other sites.

Note that all the analysis has been done in this paragraph considering the extreme values, expected in the coldest month of the year, February, and the hottest month, August. Logically all other possibilities are falling in between.

*B. Cumulative Distributions*

**Abu-Dhabi Site**: Referring to Figs. 7 and 8, in February the gases attenuation is oscillating between 2.2 dB and 2.7 dB in an interval of 0.5 dB, see Fig. 7. Salonen method is showing the highest attenuation values for all the time percentages, while Line-by-Line method is showing the lowest values during all the time percentages. The Approximation method shows values in between. For August it can be seen that the distribution is similar to the distribution in February, but the difference here in the order of 0.8 dB instead of 0.5 dB as shown in Fig. 8.

**All Sites, February and August, Approximation and Salonen methods**: In Fig. 9, the cumulative distributions of gases attenuation for all sites are quite similar and the differences are not significant for all time percentages with the exception of Al-Ain city, where the attenuation value is below the normal values by 0.1 dB. This could be attributed to the dry climate of Al-Ain city.

Fig. 10 shows that the difference of gases attenuation values in August are larger than February in the order of 0.6 dB. The six sites can be classified as follows:

**First**, Al-Fujairah shows the highest value in the order of 2.8 dB and this can be attributed to its location because it is coastal city and mountainous.

**Second**: Abu-Dhabi, Dubai, Sharjah, and Ras Al-Khaimah are four coastal cities have similar attenuation distribution during all time percentages. The attenuation value is in the order of 2.6 dB.

**Third**, Al-Ain which is the last shows the least value of gases attenuation in the order of 2.1 dB.

The same explanation is applicable for Figs. 11 and 12; with the exception that Salonen method gives higher values for all time percentages.

*C. Hourly Averaging Distributions at Different Frequencies and Elevation Angles:*

Referring to Fig. 13, it can be seen that, for low frequencies there is no significant variation in the attenuation during the day, where the variability is too small, the variations are going up gradually. The higher frequency the higher attenuation the higher variability. The curves are spread out with each increment of frequency value, but it can be observed also that there is a sudden jump of attenuation value when using frequency of 50 GHz with much higher variability. This is because the frequency is near to the resonance window of the atmospheric gases, 50 to 70 GHz [9].

Fig. 14 shows that using 90° elevation angle will results in the lowest attenuation values. This attenuation is called the zenith attenuation which is the lowest compared with other elevation angles. This is due to the fact that propagating signals at this angle will travel the shortest path through the atmosphere. In contrast, by decreasing the elevation angle, attenuation value becomes higher with small increment and variation. In case of using 10° elevation angle the attenuation becomes higher, where the signal travels longer path through the atmosphere.

## IV. Conclusions

Initial results of atmospheric gases attenuation statistics study, being conducted at Ajman University in UAE, have been presented in this paper. The surface and upper air data sets were used to obtain the slant path attenuation through the oxygen and water vapor. It was clear that attenuation caused by the dry component, between 1.8 and 2.2 dB, is usually higher than the attenuation caused by the wet component, which varies between 0.5 and 1.3 dB. However, the variability of the water vapor is higher in comparison with the variability of the dry air component. These results are useful for the microwave link power budget calculations. Value of 2 dB that represents approximately the total gases attenuation can be a crucial value for the microwave link availability. This study is to be continued to investigate the monthly and yearly distributions.


## Acknowledgements

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## References


[1] Hans J. Liebe "An updated model for millimeter wave propagation in moist air", *Radio Science*, Volume 20, Number 5, PP. 1069-1089.

[2] Salonen, S. Karhu, S. Uppala, Poiares Baptista, et al, "Modeling and Calculation of Atmospheric Attenuation for Low-Fade-Margin Satellite Communications", *ESA Journal 1992*, Vol. 16, PP. 299-317.

[3] Salonen, E., "Prediction Models of Atmospheric Gases and Clouds for Slant Path Attenuation" *Proc. of OLYMPUS Utilization Conference*, April 1993, Sevilla, Spain, pp. 615-620.

[4] Feldhake, G. "Estimating the Attenuation Due to Combined Atmospheric Effects on Modern Earth-Space Paths" *IEEE A&P Magazine*, Vol. 39, No. 4, August 1997, pp. 26-34.

[5] K. Al-Ansari, P. García, J.M. Riera, A. Benarroch, "Slant Path Measurements at 50 GHz in Madrid: Attenuation by Gases and Clouds", *IEEE 2000 APS, International Symposium and USNC/URSI National Radio Science Meeting*, July 2000, Salt Lake City, Utah, USA.

[6] Kifah H. Al-Ansari, Pedro García del Pino, José M. Riera Salís, Ana Benarroch, "Experimental attenuation by gases and clouds in Madrid using Italsat 50 GHz beacon", *IEE Eleventh International Conference on Antennas and Propagation ICAP2001*, April 2001 Manchester (UK), Conference publication Nº 480,Vol. 2, pp. 830-834.

[7] Salonen, E. "Prediction Method for Oxygen Attenuation on Slant Propagation Path for 10-57 GHz", *IEE Antennas and Propagation Symposium*, Digest 1991, Vol.3, PP. 1804-1807.

[8] Salonen, E, Uppala, S. and Aulamo, H. I., "Prediction of water vapour attenuation on a slant path", *Eighths International Conference on Antennas and Propagation, IEE*, April 1993, PP. 64-67.

[9] Recommendation ITU-R. P-676-6, "Attenuation by Atmospheric Gases", 2005.


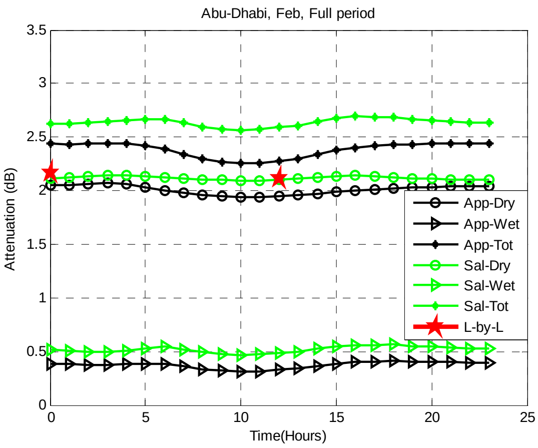


Fig. 1. Hourly averaging of gases attenuation

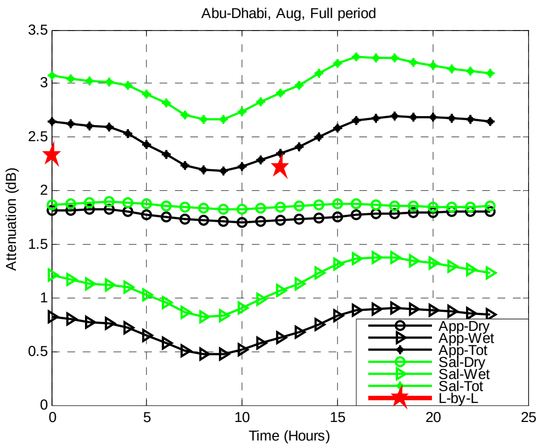


Fig. 2. Hourly averaging of gases attenuation

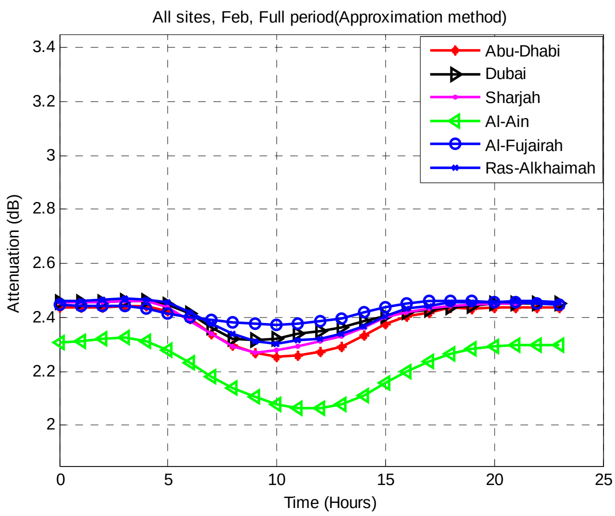


Fig. 3. Hourly averaging of gases attenuation for all sites

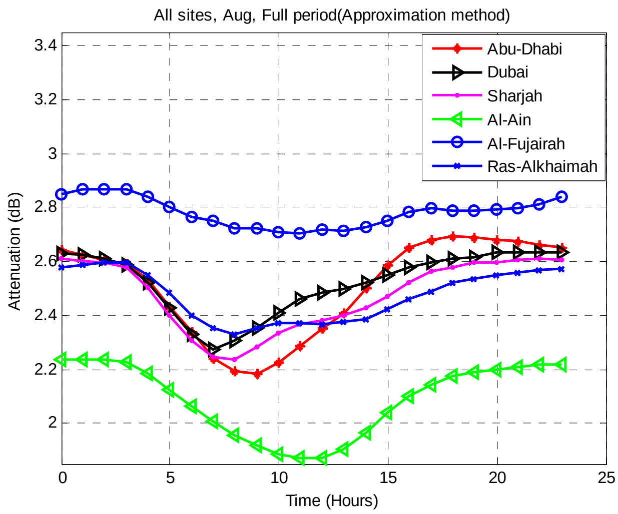


Fig. 4. Hourly averaging of gases attenuation for all sites

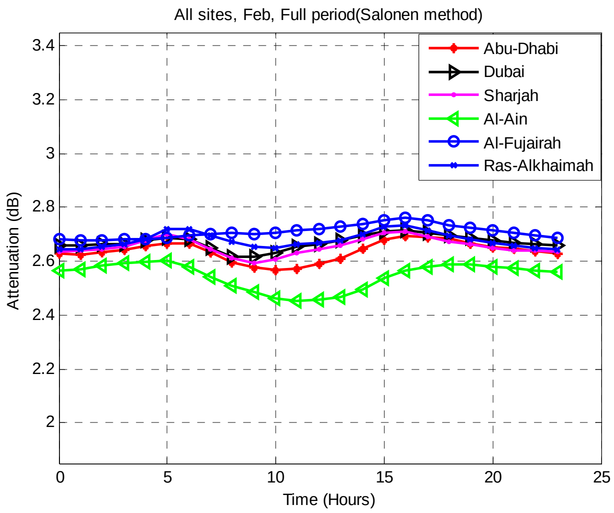


Fig. 5. Hourly averaging of gases attenuation for all sites

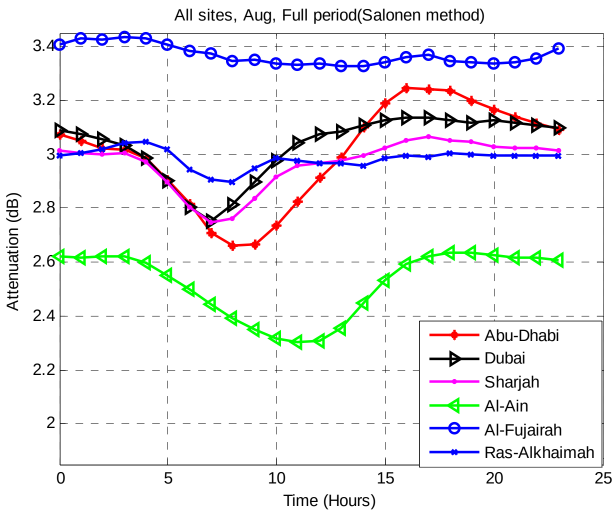


Fig. 6. Hourly averaging of gases attenuation for all sites

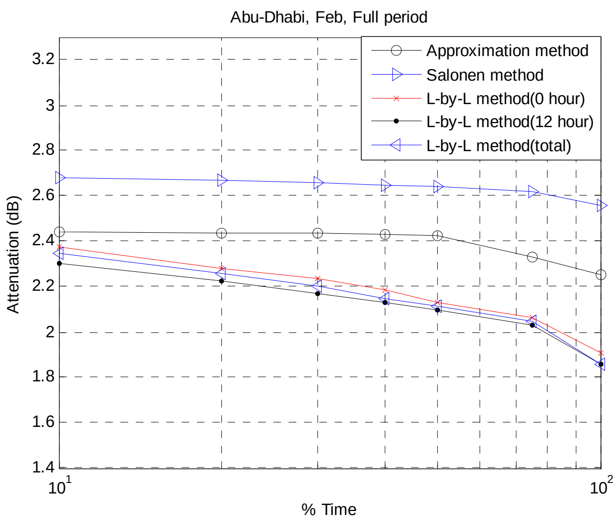


Fig. 7. Cumulative distribution of gases attenuation in Abu-Dhabi

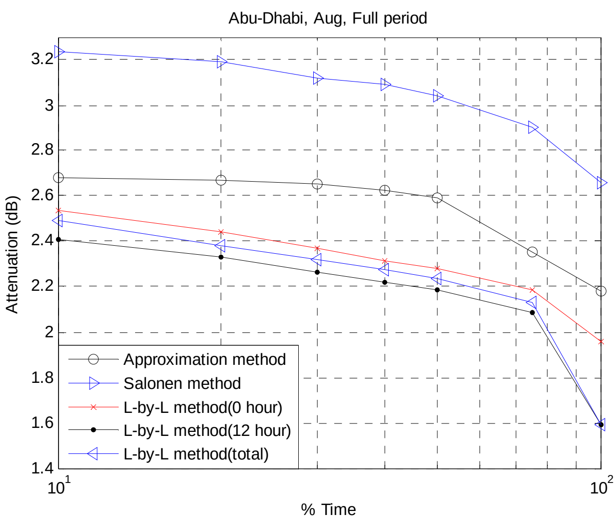


Fig. 8. Cumulative distribution of gases attenuation in Abu-Dhabi

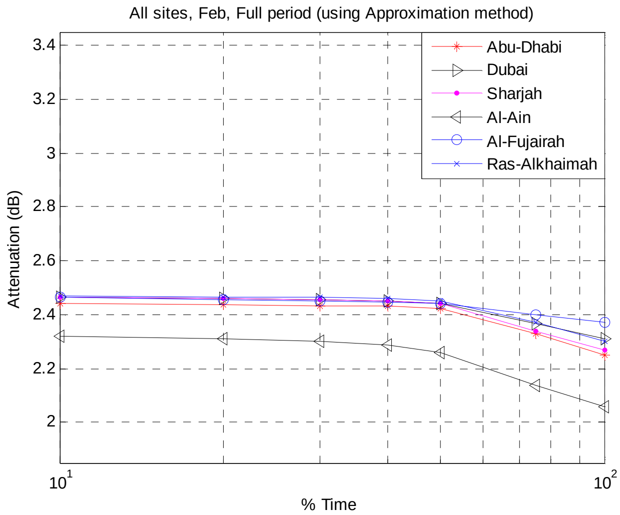


Fig. 9. Cumulative distribution of gases attenuation for all sites

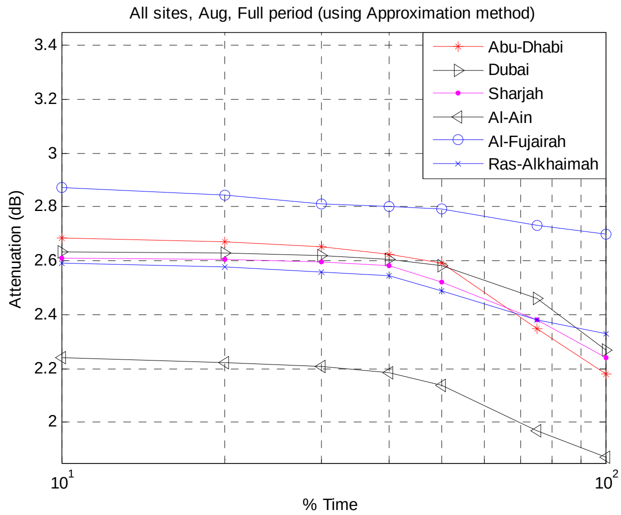


Fig. 10. Cumulative distribution of gases attenuation for all sites

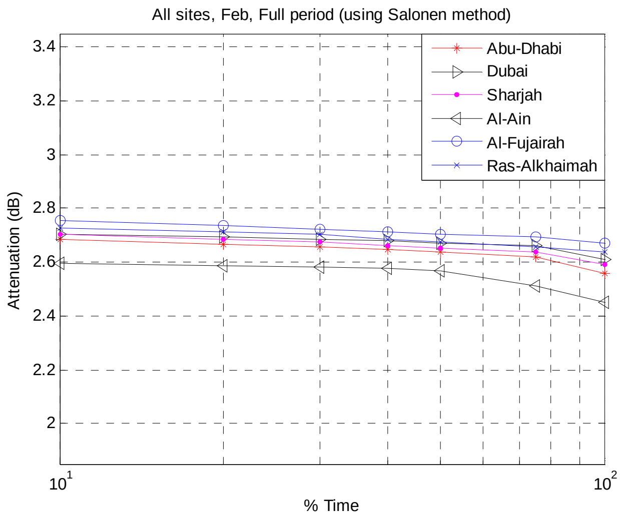


Fig. 11. Cumulative distribution of gases attenuation for all sites

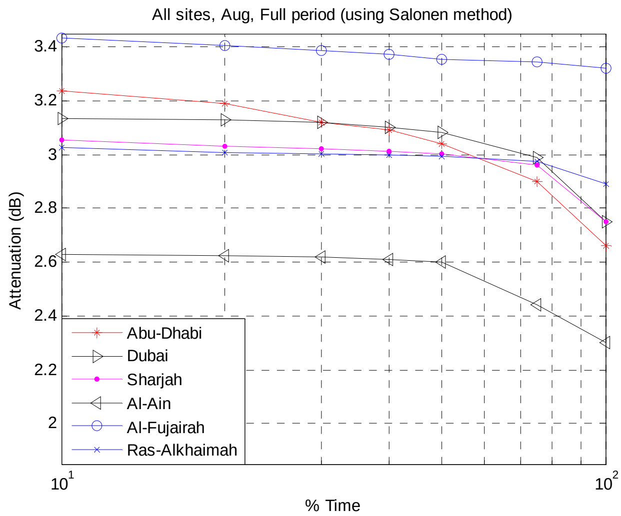


Fig. 12. Cumulative distribution of gases attenuation for all sites

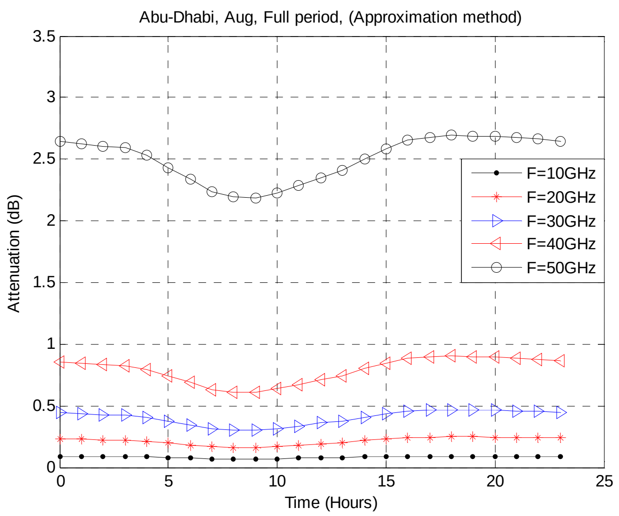


Fig. 13. Hourly averaging of gases attenuation at different frequencies

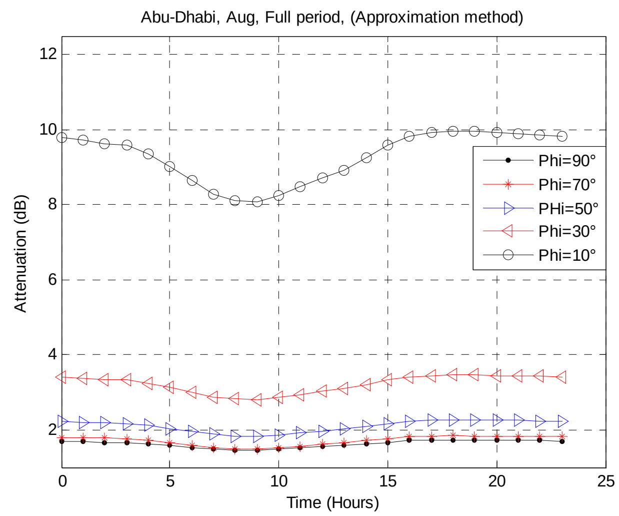


Fig. 14. Hourly averaging of gases attenuation at different elevation angles