Signal Propagation for Satellite Communications on Iraqi Territory: Measurements and Simulation

H. A. H. Al-Behadili, M.N.S. Almaliki

Abstract*: In the last sixteen years, there has been an increment in the use of Satellite communications in Iraq. It is generally used in every home in this country. However, the quality of the signal coming from different Satellite providers is still not optimised. There are several reasons which affected this service such as engineering issues and physical impact. Therefore, there is a necessity for studying this topic and focus the light on the main problems that could hinder the improvement of Satellite communications. This paper attempt to present a model that can be employed for prediction of a communication signal from the satellite and the several issues related to that model. The model is constructed from gathering various models and concepts that are necessary to consider such as the effect of non-ionised atmosphere and the ionosphere. In addition to reviewing the effect of gains from the antenna which contained in the specific equation of defining the signal power. Finally, the simulation results were compared with the outcome from measurements to examine the system reliability.

***Keywords* : Satellite, ITU-R, propagation, atmosphere, ionosphere..**

I. INTRODUCTION

The development of Satellite communications (SAT COM) after the Second World War in the last century triggered a significant amount of innovative scientific investigations. After that, there was a growth in the Satellite industry until it reached to point of utilising Satellite communications as a tool to broadcast TV channels. Although the obvious employment of SAT COM is to be used in civil issues, the original reason to develop SAT COM was for military issues. Recently, there has been an increased interest in studying SAT COM situation with 5G evolution. The most noticeable feature with the advancement is the frequency of use, in other words, it is now higher than when it has first appeared. The reader is referred to [1-3] for very detailed information about SAT COM. However, there is here an interest in monitoring the Earth-space link to obtain better service.

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There are three parts for SAT COM: the communication satellite which is in orbit (in the space), the ground stations and the user. Through this paper, there is an interest in modelling the signal along the path between the satellite and the receiver at the ground station.

II. PROPAGATION EFFECT ON SATELLITE SIGNAL

Different parameters could affect the performance of Earth-space communication channel. These have been already defined by the International Telecommunication Union [4]. They can be classified into physical (include: tropospheric and ionospheric effects) and engineering issues (antenna design and power). Because of various situations in the Earths' weather, lower atmospheric (tropospheric) effects have considered a very complex area, and its impacts need to be considered. As well as the ionosphere has a significant effect on the signal characteristics, which include scintillation, absorption, group delay.etc. Earlier studies such in [5] discuss the issues of parameters that have effects on satellite signals, particularly through the ionosphere. The section has attempted to yield brief concepts of the parameters that are necessary to design a model for this paper. To conclude this section, the literature identifies the relationships between several parameters and the satellite service performance

III. METHOD AND DISCUSSION

Many researchers have utilised models to predict the channel of the Earth-space link [6-7]. Most of those studies adopt empirical models in the construction of their databases. However, it is interesting to enhance performance by considering more data that are necessary to be considered. It was considered that exhaustive models would usefully supplement to the researchers. In other words, the model developed in this paper has included an algorithm which considered both physical and engineering parameters to estimate the signal characteristics since it is intended to employ the outcome of this model in broadcasting applications and point to point communications.

The purpose of this investigation is to predict the signal power after considering all the discussed effects. For line budget calculations, it can be started by the general line budget formula [8]:

$$P_r = P_t + G_t + G_r\text{-Loss} \qquad (1)$$

Where, P_r is the recived power in (dB), P_t is the transmitted power (dB), G_t, G_r gains for both tranmitter and reciver antenna. This mathematical formula used in this paper as a destination function for a set of Matlab functions as shown in Figure 1.

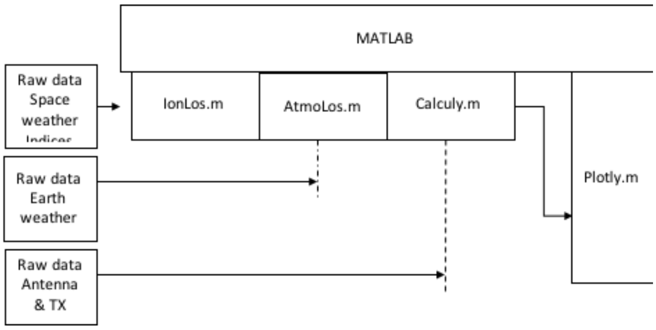

Fig. 1 Model Work Flow Diagram

There are there parts for input data that are necessary to drive the model: space weather data, the weather data and antenna parameters. Space weather data extracted from OMNI web https://omniweb.gsfc.nasa.gov which include the hourly mean values of the interplanetary magnetic field (IMF) and solar wind parameters measured by various spacecraft in addition to geomagnetic and solar activity indices and energy proton fluxes. Data for Earth's weather can be provided currently by a local weather data provider (http://www.meteoseism.gov.iq). Antenna gains are required for accurate calculations of final signal strength; therefore, gains were considered in this paper. There are three parts to use for gains: isotropic (as a reference to compare), selective antenna (the normal antenna types, and particular relevance with the research filed is the parabolic antenna which is estimated using the following equation:

$$G = \eta(\frac{\pi D}{\lambda})^2 \qquad (2)$$

Where, η: is the efficiency of the antenna, D: dish diameter and λ is the wavelength.

The path loss employed in equation (1) can be calculated by considering the effects of the non-ionized atmosphere and the ionised atmosphere (the ionosphere). The regular recommendations report from the International Telecommunications Union (ITU) has been adopted to cover most of the path loss characteristics.

Figure 2 illustrates the effect of frequency and distance on the free-space loss. The loss is increased with both the distance and frequency.

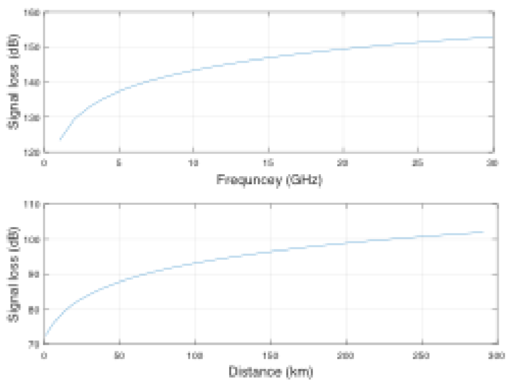

Fig.2 Free space loss in terms of frequency (above) and distance (below).

In the last years, the rate of rains has been significantly increased over Iraq territories. However, this has a negative impact on some occasions on communication services in this country. During intensive rain status, particularly with the presenting of thunderstorms, it has been noticed that there is nearly block out of satellite signals, which need to consider such occasions to plan in the future.

The below results have been simulated by using ITU recommendations for various losses effects. The real-time data are mostly obtained from Iraqi Meteorological Organization & Seismology records (http://www.meteoseism.gov.iq) and few regular records from Misan Province. In most occasions, Misan province in the south of Iraq was taken as an example, and the frequencies were taken per the records used in this field.

Figure 3 the specific attenuation due to dry air in the frequency range 10 to 120 GHz using (ITU-R P.676-5, Annex 2) [9]. The Figure has reproduced the curve on page 15 in ITU-R P676-5 but here it has been used seasonal records for Misan province in Iraq with 10-120 GHz rather than 1 to 350 GHz. There is a slight difference between all the four seasons records which indicates the amount of effect of dry air.

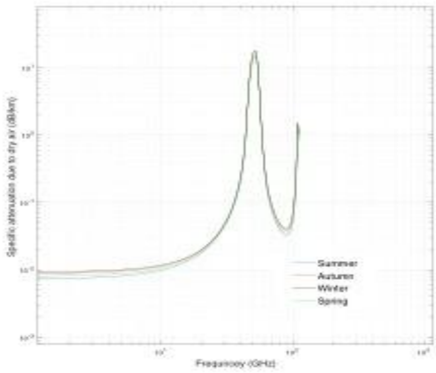

Fig. 3 Seasonal dependence of attenuation due to dry air for Misan province (2018 records).

Figure 4 shows the specific attenuation due to water vapour in the frequency range 10 to 120 GHz (ITU-R P.676-5, Annex 2). The figure reproduces the curve on page 15 in ITU-R P676-5 but also with Misan province.

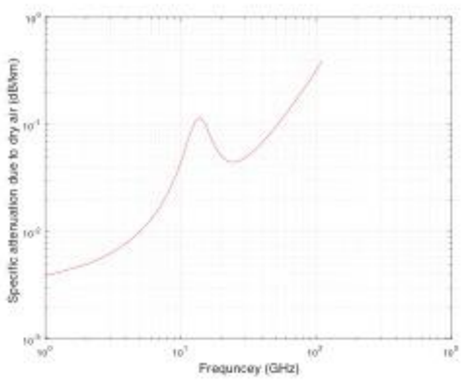

Fig. 4 Specific attenuation due to water vapour in frequency range 10-120 GHz for Misan province October 2018 records.

As been mentioned, the records of rains have been climbed particularly in 2018, therefore it is necessary to estimate the effect of rain attenuation. Figure 5 the rain attenuation statistics from point rainfall rate using ITU-R P618.7 [4] and the absorption due to hydrometeors according to the System for Atmospheric Modelling (the SAM model) developed by Marat Khairoutdinov [1]. The red curve (using the ITU model) has discontinuity just above 55 GHz where it is out of range of the model. However, there are no interesting results above this value of frequency even with the SAM model.

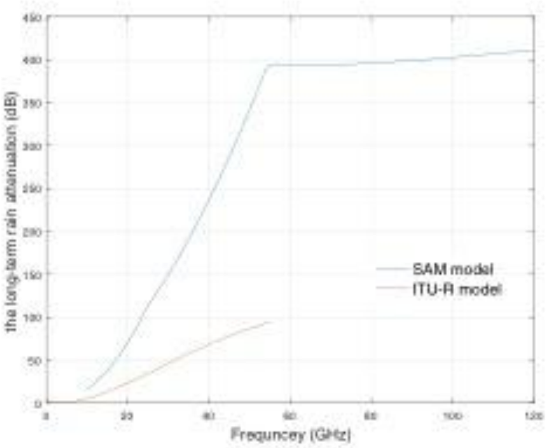

Fig. 5: Attenuation due to rain (ITU) and SAM model.

In addition to the above attention effects, the system was incorporated other types of losses in the non-ionised region of the atmosphere, such as dust and sand effect using the model in [10], which are very noticeable in the area of interest. There are also other areas of investigations that were embedded in the model such as site diversity and cross polarisation effects, those have been developed in [1] and [3].

The effects of lower parts of the atmosphere were collected in the main function AtmoLos.m which given in Figure 1.

The losses and attenuation caused by the upper part of the atmosphere (the ionosphere) include the propagation delay that is in Microseconds, the dispersion effect in addition to the change of direction due to the signal passage through the ionosphere such as the refraction, change of direction of arrival. The prominent impact of the ionosphere is the signal absorption that could cause a signal power degradation may reach more than 1 dB in less than GHz frequencies. In addition to ionospheric scintillation which is mostly noticeable on the regions far from the mid-latitude zone [11]. Most of the ionospheric prediction parameters that are necessary for SAT COM can be found in [12]. In the program employed for this paper, the main function of IonLos.m has a procedure to evaluate the ionospheric impact on the signal coming from the satellite. The ionospheric delay effect can be normally migrated by knowing the amount of the Total Electron Content (TEC) along the ionospheric path. There is a sub-function to be called which utilised to extract the necessary data to calculate TEC. The Matlab script IonLos.m was utilised to cover all the ionospheric effects.

Ultimately, all the required calculation of signal power was performed using the function Calculy.m, and Plotly.m script can be used to plot out the outcomes. Then an experimental work was performed following experimental setup that previously done in [13] with more analysis.

The results of the model were compared with measurements of satellite signal strength received at a system consist of the receiver device, a parabolic antenna has 90cm feed with LNB (Low noise down convertor) this is connected to the satellite receiver system via coaxial cable. To extract the signal strength, a spectrum analyser has been utilised to pick up the signal symbols for more analysis (e.g. obtain the signal strength for comparison) since it is complicated to measure that from the receiver directly. The symbols were collected in a form of matrix every which have rows with 600 symbol and the time of collection in microseconds. The data then were stored into a PC and using Matlab script to read through the signal strength data. However, the SHF (Super High Frequency) were received from Nilesat 201 W 7.0･ satellite in October 2018 (rainy day) in Misan Province- Iraq at 4:03 AM. At the time, the measured downlink frequencies were 10 Up to 13 GHz.

In view of reliability, the model has been iterated many times to force the results in agreement with the measurements. Figure 6 and 7 are the measurements and modelling of the satellite received signal that processed concerning their original dot plots (in the model and measurements) to fill the gap and cut down the higher and lower frequencies. The processing was performed using a smoothing function in Matlab environment. As expected, the model has a smooth output as compared with the measurements. There is a general interesting agreement on specific occasions between the simulation and the measured values. The times that showing decrements in signal power were experiencing thunderstorms with heavy rain. At 13 GHz, the signal was the worst amongst the other frequencies at both modelling and measurements. The other frequencies show interference between them with a preference of 11 MHz.

The current study found that there is a possibility to predict the signal of SAT COM. The compassion of the modelling with those of the measurements confirms that possibility. Further work is required to confirm and validate the model output.

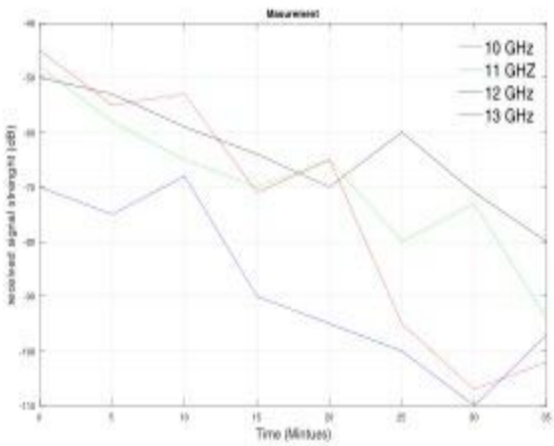

Fig. 6 the satellite recived signal strenght (measurements)

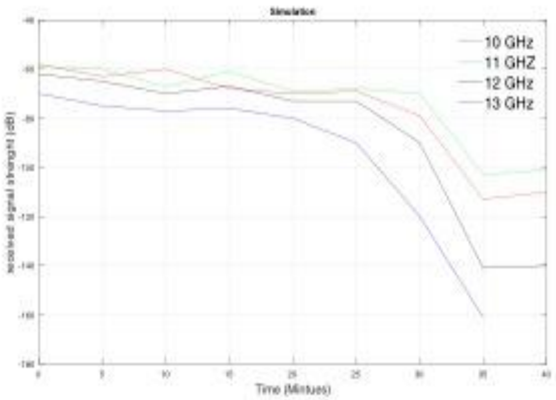

Fig.7 the satellite recived signal strenght (Simulation)

IV. CONCLUSIONS

The main project was undertaken to find the best state of art of joining the prediction of SAT COM with 5G. The study of this paper set out to objectively predict the signal power coming through the Earth-space link and how is affected by several parameters. In general, it seems that there is a demand to consider the relationship between the signal power and the discussed parameters. An implication of the comparison between the measurements and simulation is the possibility that the model works for forecasting the satellite signal strength can be designed in a better way.

It would be interesting to assess several factors such as diurnal and seasonal variations, symbol rate choices…etc. A further study could assess the long-term results coming from the model. This is also to consider the evolution of 5G technology.

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REFERENCES

1. Timothy, Pratt, W. C. Bostian, and Jeremy E. Allnutt. "Satellite communication." *John Wilcy and Sons, NJ* (2003).
2. Evans, Barry George, ed. *Satellite communication systems*. Vol. 38. Iet, 1999.
3. Ha, Tri T. *Digital satellite communication*. Tata McGraw-Hill Education, 1990.
4. Series, P. "Propagation data and prediction methods required for the design of Earth-space telecommunication systems." *Recommendation ITU-R* (2015): 618-12.
5. Rush, C., J. Aarons, F. Stewart, J. Klobuchar, P. Doherty, M. Pokempner, and R. Reasoner. "Study of factors affecting an HF/VHF direct broadcasting satellite service." *NASA STI/Recon Technical Report N* 85 (1984).
6. Al-Saegh, Ali Mohammed, A. Sali, J. S. Mandeep, Alyani Ismail, Abdulmajeed HJ Al-Jumaily, and Chandima Gomes. "Atmospheric propagation model for satellite communications." In *MATLAB Applications for the Practical Engineer*. IntechOpen, 2014.
7. Shu, Zhihui, Xin Tian, Gang Wang, Dan Shen, Khanh Pham, Erik Blasch, and Genshe Chen. "Mitigation of weather on channel propagation for satellite communications." In *Sensors and Systems for Space Applications IX*, vol. 9838, p. 98380J. International Society for Optics and Photonics, 2016.
8. Haykin, Simon S., and Michael Moher. *Modern wireless communications*. Pearson Education India, 2011.
9. ITU-R, Rec. "P. 676-5: Attenuation by atmospheric gases in the frequency range 1÷ 350 GHz." *Propagat. Non-Ionized Media* (2001).
10. Harb, Kamal, Omair Butt, Samir Abdul-Jauwad, and Abdulaziz M. Al-Yami. "Systems adaptation for satellite signal under dust, sand and gaseous attenuations." Journal of Wireless Networking and Communications 3, no. 3 (2013): 39-49.
11. Banerjee, P. K., R. S. Dabas, and B. M. Reddy. "C and L band transionospheric scintillation experiment: Some results for applications to satellite radio systems." *Radio Science* 27, no. 6 (1992): 955-969.
12. Recommendation, I. T. U. "Ionospheric propagation data and prediction methods required for the design of satellite services and systems P series radiowave propagation." P.531-11, (2012).
13. Bačić, Iva, and Krešimir Malarić. "Measurements of ASTRA Satellite Signal Parameters." In *8th International Conference MEASUREMENT 2011*. 2011.

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