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Comparative Study of Estimation of Rain and Cloud Attenuation at High Frequency on Satellite Links for Mongolia

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Abstract:- The countries of the world are using various communication services in all areas of society on based satellite networks. The International Telecommunication Union has allocated two kind of satellite positions in Geo-Synchronous Orbit (GSO) space to Mongolia that are 113.6E longitude for Fixed Satellite Service-(FSS) and 74E longitude for Broadband Satellite Service-(BSS). Therefore, Mongolia is planning to launch its national satellite in 2030.

Thus, we are studying many kind of science research including estimate satellite geometry parameters, rain attenuation, cloud attenuation and satellite network architecture on based national satellite that will be deployed to space segment.
The purpose of this research work is to predict the estimation of rain and cloud attenuation based on the national satellite link that will be launched at space segment 113.6 E from Mongolia. First, it is defined requirements of propagation effects of satellite communication and analyze some related research work and literature. Then, it is calculated geometry parameters of geostationary satellite, the look angles of ground station antenna by using mathematical model by each regions of Mongolia. It is important to calculation rain and cloud attenuation. After that, to estimated calculation of rain and cloud attenuation by using ITU-R mathematical model by each region for Mongolia. Finally, we analyzed comparative study of calculated result of rain and cloud attenuation to show some result.

***Keywords**:- Geometry parameter, rain attenuation, cloud attenuation, ITU-R model, Satellite frequency*

I. INTRODUCTION

In satellite communication link, the electromagnetic waves carrying the signals travel the most part in free space, which is near vacuum. For near-earth orbit satellites, the major part of propagation is in the atmosphere. There are losses encountered by the signal in the region close to the earth. The loss of signal in terms of attenuation is very common problem.

Signal attenuation can cause degradation in the Quality of service (QoS) in wireless communication. Networks operating over high frequency bands are highly affected by signal attenuation [1].

For geostationary satellites, the path through the atmosphere may be just about 3% of the total path length: however, for low earth orbit satellites, it is almost 100%. The atmosphere comprises many elements that effect the signals in different ways. These include various losses of the signal strength and phase changes causing degradation in the received signal.

These losses are due to atmospheric absorption and attenuation, cloud attenuation, rain attenuation, tropospheric and ionosphere scintillation, faraday rotation, and rain and ice crystal depolarization. The effects of the atmosphere are also frequency dependent [2].

II. LATERATURE OF RAIN ATTENUATION IN SATELLITE NETWORK

Rain attenuation is considered as the dominant impairment as it gives rise to the largest amount of loss. This loss results in a degradation of the satellite to ground link and therefore affects the reliability and performance of satellite communication links.

Hammed O. Busari and Olaosebikan A. Fakojugo studied using propagation modelling, the point rainfall and rain effects for frequencies was concurrently considered between 11 and 40 GHz for satellite communication service on earth-space path at Ibadan in Oyo state, Nigeria by using rainfall data for the period of five (5) years.

They defined that is to increase in attenuation was experienced at 40 GHz with a value of 112.33dB and the least is at 11 GHz with a value of 11.76dB. Hence pronounced rain attenuation is experienced in Ibadan at both the downlink and uplink frequencies of ka-band. Results achieved will be helpful to communication engineers and proposed consumers of services from various satellite outfits [3].

Researchers of the universities in Malaysia studied rain attenuation and defined some results. They calculated rain attenuation by two kind of model including ITU-R and DAH model by using six months of measured rain attenuation data.

This research is reported that the effect of rain attenuation on communication systems has been of great interest to many researchers; however, limited investigations in the tropics have been reported [4].

Attenuation by rain intensity depends on the millimeters rain rate of accumulation per hour and not on the total rain accumulation (Ezeh et al., 2014).

Atmospheric effect is the major factor to be considered in design of satellite-to-earth links operating at frequencies above 10 GHz. Raindrops absorb and scatter radio waves, leading to signal attenuation, thus reduce the system availability and reliability (Yussuff et al., 2018) [5].

III. LATERATURE OF CLOUD ATTENUATON

A cloud is consisting of mass of very small water droplets, ice crystals, super cool water or some suspended particles present in atmosphere. The formation of clouds is due to saturation of atmospheric air, which is the result of cooling of air at dew point. It is also formed when it gets sufficient moisture from its surroundings in order to raise due point to ambient temperature.

Various researchers in past has done lot of research on cloud attenuation. Some has proposed models on cloud attenuation. Researchers of the universities in Pakistan studied the comparative study of such empirical models which provides the cloud attenuation considering frequency, elevation angle and liquid water content as input parameters. They defined liquid water content and frequency is directly proportional to cloud attenuation while at lower elevation angle the cloud attenuation is higher. All the models approximately show same attenuation, but the DAH model is more accurate as compare to the other models because it gives the lower attenuation. For future work, the results obtained can be combine with the effect of haze (vapors, mist, fog, smog) and clouds having ice particles for the better estimation of cloud attenuation [6].

Ehikhamenle M and Edeko F.O studied analyses the cloud attenuation effects of communication signals at frequencies of 20-50GHz in the southern region of Nigeria. The methodology adopts the modified model for specific attenuation due to cloud postulated by Lorenzo and Capsoni. The values of specific attenuation under the given conditions of cloud cover were computed by using the absorption coefficient of cloud liquid water a wand not the traditional use of directly compute cloud liquid water content.

They defined this further buttresses the fact that absorption coefficient is independent of site/location atmospheric data and this model will be suitable for analysis in other locations with a different climate to the study locations [7].

IV. STUDY AREA

Mongolia is located in Northeast Asia as a landlocked country. Mongolia is the 7th largest country in Asia and 17th largest in the world. It bordered by 2 countries with Russia and China. With an area of 1.5 million square kilometers, the land shape on the map looks like roughly oval. Fig.1, is shown Mongolian map [8].

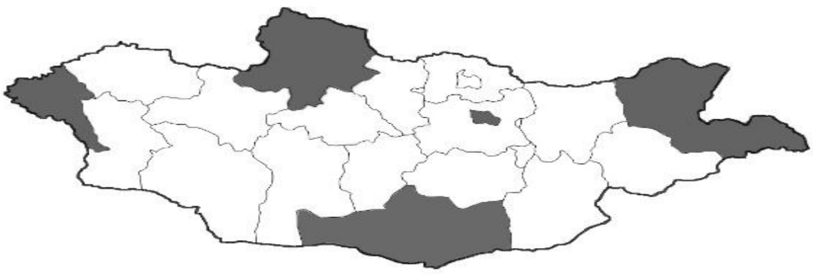

Fig. 1: Map of Mongolia and selected provinces

Mongolia is divided into 5 regions by physical geography. We have selected one province from each region. The main coordination is in Mongolia that the west coordination is Bayan-Ulgii, the east coordination is Dornod, and cental coordination is Ulaanbaatar, as well as the north coordination is Khuvsgul and the south coordination is Umnugovi. The longitude, latitude, and altitude of these provinces are shown by Table. I [9].

Table 1: Longitude, latitude and altitude of provinces

Zone	Province	Longitude	Latitude	Altitude
Central	Ulaanbaatar	106.92 E	47.92 N	1350 m
North	Khuvsgul	100.15 E	49.64 N	1300 m
West	Bayan-Ulgii	89.97 E	48.97 N	1715 m
South	Umnugovi	104.43 E	43.57 N	1263 m
East	Dornod	114.53 E	48.08 N	713 m

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Mongolia is divided into 21 provinces (aimags) and subdivided into 331 village (soums). These provinces and capital city into divided 5 regions.

It means that these provinces are located much different geography and climate. Mongolia located within longitude from 87.44E to 119.56E and latitude from 41.35N to 52.09N. These selected provinces are included in border points of the Mongolia.

The geometry parameters will be estimated by mathematical model in selected provinces of study area. As estimated the geometric calculation of satellite communication through these selected provinces, it can have covered the whole of Mongolia in terms of geographical location.

A. Mongolian climate-rainfall season and cloud.

Mongolia is a landlocked country to located in East and Central Asia bordered by Russia and China. The geography of Mongolia is varied with the Gobi Desert to the south and mountainous regions to the north and west.

All in all, the weather pattern is very variable over short periods of time. Mongolia has a strongly continental climate with long, cold winters and short summers. There is a short rainy season in June, July and August during which most of the annual rain falls. Around 70 percent of all precipitation falls during these three summer months.

Generally, there is not much precipitation in Mongolia and the mountains get slightly more rain. The average of rainy days in mountains regions of Mongolia is 60-70 days.

Precipitation is more abundant in the north, where it exceeds 300 mm per year, while in the south, which is desert, it drops below 200 mm per year. Average precipitation of capital of Mongolia is shown in Fig.2.

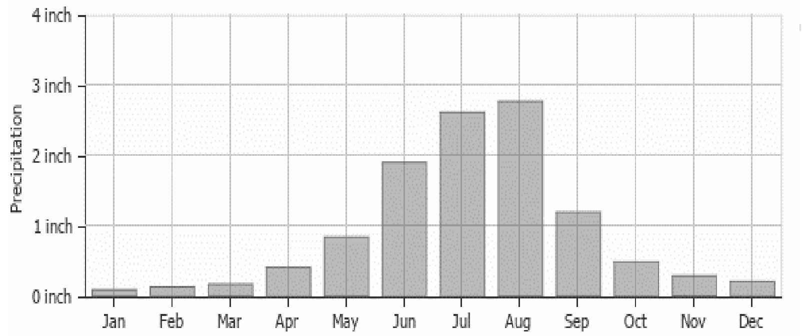

Fig. 2. Average precipitation (rain/snow) in Ulaanbaatar, Mongolia-2022 [10]

As well annual precipitation rarely exceeds 400 mm and is typically much lower in the south and central desert and steppe regions. In Gobi Desert annual rainfall is only around 40 mm.

In Mongolia, clear skies are frequent throughout the year, so there's plenty of sunshine. The sunniest season is spring. In summer, the number of cloudy days increases a bit on account of the aforementioned Asian monsoon. Cloud over and precipitation is more pronounced in Mongolia mountainous and forested north and decreases southwards through rolling steppe and semi-desert.

There are mostly cumulus clouds in sky of Mongolia. Mongolian cloud information is shown by date: 17. Feb.2023 in Fig.3

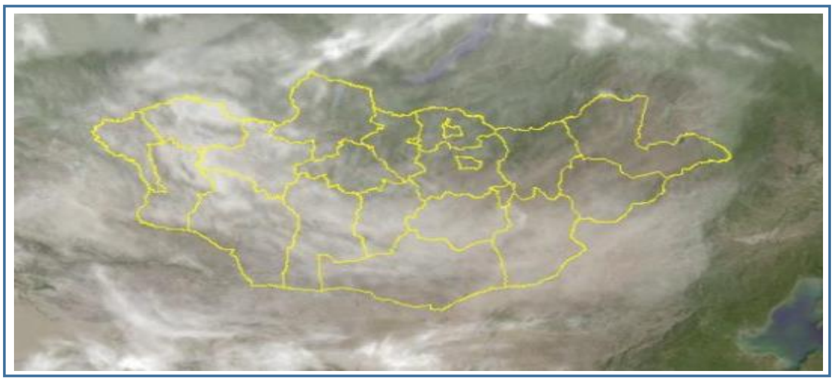

Fig. 3: Cloud satellite imagine of Mongolia

Mongolia is known as the Land of the Blue Sky and throughout the year, there are 278 sunny days and 9-23 cloudy days [11]. All in all, the weather pattern is very variable over short periods of time.

V. CALCULATION OF GEOMETRY PARAMETERS, ITS METHODOLOGY IN MONGOLIA

The geometry parameters including slant range, look angles of earth station antenna based on longitude and latitude of these selected provinces. It is important to determine the factors affecting, propagation effects, and the reliable of satellite system to calculate satellite geometry parameters.

Particularly, it is very important to result of calculation of geometry parameter to will be calculated by rain and cloud attenuation of the national satellite 113.E in space position to be launched in Mongolia.

A. Geometry parameters calculation in Mongolia

Depending on the longitude and latitude of the satellite and earth station, the distance between the stations and the azimuth and elevation angle of antenna are different.

The geometry parameters will be estimated by mathematical model in selected provinces of study area.

- *Step 1:*

Calculate of the slant range-In radio electronics, slant range is the line-of-sight distance between two points which are not at the same level relative to a specific datum.

$$R = (r_e^2 + r_s^2 - 2 * r_e r_s \cos\gamma)^{\frac{1}{2}} \quad (3.1)$$

Where:

- $r_{(e)}$ – The radius of earth=6378 km
- r – The altitude of GEO orbit=35786 km.

The radius of satellite-$r_{(s)}$ consists earth radius and altitude of GEO orbit.

- *Step 2:*

Calculate of the azimuth angle is the angle between the earth station meridian and the line joining the earth station and sub-satellite point.

$$\sin(A_z) = \frac{\sin(\Delta\lambda)}{\sin\gamma} \quad (3.2)$$

Where:

- Δλ – Difference of longitudes of the earth station and satellite
- γ – The central angle.

$$A_z = \sin^{-1}(\sin A_z) \quad (3.3)$$

- *Step 3:*

Calculate of the Elevation angle-The elevation angle-θ, of earth station antenna, the angle measured upward from the local horizontal to the satellite obtained follow formula.

$$\cos\theta = \frac{r_s}{R} * \sin\gamma \quad (3.4)$$

Where:

- r(s) – The radius of satellite
- R – The slant range
- γ- The central angle

Hence, elevation angle θ is

$$\theta = \cos^{-1}\cos(\theta) \quad (3.5)$$

The geometric calculation of the satellite communication in selected provinces is calculated by mathematical modeling at the space position 113.6 E. Estimated result of geometry parameter is shows in Table. II.

Table 2: Estimated result of geometry parameters

Province	Slant range [km]	Look angle of earth station antenna	
		Azimuth	Elevation
Ulaanbaatar	38213	171.04^0	34.5^0
Khuvsgul	38463	162.6^0	31.6^0
Bayan-Ulgii	38662	150^0	28^0
Umnugovi	37865	166.8^0	40^0
Dornod	38196	181.26^0	35^0

B. Result of section:

If elevation angle of the earth station antenna is less more than 5 degrees not used in satellite system.

As shown in table 2.2, the elevation angle of the earth station antenna is **(28^0-40^0)** degrees for the satellite position **113.6 E** in Mongolia. Therefore, it shows good characteristics that these elevation angle parameters are suitable to develop satellite network at space position 113.6 E for Mongolia.

VI. CALCULATION OF RAIN ATTENUATION, ITS METHODOLOGY IN MONGOLIA

The International Telecommunication Union (ITU) has created a statistical model in which the Earth is divided into 15 different „rain zones" where each zone corresponds to a certain level of rain rate.

According to ITU-R PN.837-1 model, Mongolia is related in two kind of zones that are Zone A-(<8 mm/hr.) and Zone E-(<22 mm/hr.) for 0.01 percent of annual rain intensity [12]. It is covered the most land areas of Mongolia are included in the E rain regions, and the southwestern part is included in the A rain region.

A. Rain attenuation calculation in Mongolia.

ITU-R model applies rain rate at 0.01% probability level for attenuation estimation and then uses an adjustment factor the predicated rain attenuation depth for other probabilities [13].

The steps required for the analysis are given below: [14].

- *Step 1:*

Determine the rain height, H_R as:

$$h_R = h_o + 0.36 \text{ [km]} \tag{4.1}$$

$h_{(0)}$ is upper atmosphere altitude at which rain is in the transition state between rain and ice. The rain height is defined in km above sea level [10].

- *Step 2:*

Determine the slant path length $L_{(s)}$, below the rain height is given by:

$$L_S = \frac{h_R - h_S}{\sin(\theta)} \text{ [km] for } \theta \geq 5^0 \tag{4.2}$$

Where $h_{(s)}$ (km) is the altitude of Earth station above sea-level and θ (degree) is the elevation angle between the horizontal projection and slant path.

- *Step 3:*

The horizontal projection of slant-path length, $L_{(G)}$, (km) is calculated as:

$$L_G = L_S \cos(\theta) \text{ [km]} \tag{4.3}$$

- *Step 4:*

Point rainfall rate $R_{(0.01)}$ (mm/h) exceeded for 0.01% of an average year from one-minute integration rain rate data.

- *Step 5:*

Obtain the specific attenuation, γ_R-(dB/km) for 0.01 of time as given by:

$$\gamma_R = k * R_{0.01}{}^{\alpha} \text{ [dB/km]} \tag{4.4}$$

Parameters k and α can also be obtained from ITU-R P.838-3

- *Step 6:*

The horizontally adjusted path reduction factor $r_{(0.01)}$ for 0.01% of time is given by:

$$r_{0.01} = \frac{1}{1+0.78\sqrt{\frac{L_G \gamma_R}{f}} - 0.38(1-e^{-2L_G})} \tag{4.5}$$

Where f-(GHz) is the operating frequency, so that the horizontally adjusted rainy slant path length is calculated from:

$$L_R = \frac{L_G r_{0.01}}{\cos\theta} \text{ for } \zeta > \theta \text{ [km]} \tag{4.6}$$

Otherwise,

$$L_R = \frac{h_r - h_s}{\sin\theta}, \text{for } \zeta \leq \theta \text{ [km]} \tag{4.7}$$

Where,

$$\zeta = \tan -1 \left(\frac{h_R - h_s}{L_G r_{0.01}}\right) \text{ [degree]} \tag{4.8}$$

- *Step 7:*

The vertical reduction factor $r_{(0.01)}$ for 0.01% of time is also given by:

$$v_{0.01} = \frac{1}{1+\sqrt{\sin\theta}\left[31-e^{-\left(\frac{\theta}{1}+x\right)}\right]\sqrt{\frac{L_R \gamma_R}{f^2}} - 0.45]} \tag{4.9}$$

- *Step 8:*

Finally, the effective path length L_E (km) through rain is obtained by multiplying the horizontally adjusted slant-path by the vertical reduction factor, as follows:

$$L_E = L_R V_{0.01} \tag{4.10}$$

- *Step 9:*

The predicted rain attenuation exceeded for 0.01% of an average year is obtained from:

$$A_R = \gamma_R * L_e \text{ [dB]} \tag{4.11}$$

B. Methodology of Rain calculation.

Then related date of rain intensive for 0.01% of year and rain zone category are defined from worldwide map of ITU-R rain regions.

Also, altitude of provinces in study area defined from source of “Geodetic coordinate and altitude of Mongolia” in Agency for Land Administration and Management, Geodesy and Cartography. These collection data are shown Table. III.

Table 3: Data Collection

Earth station location	**Altitude [m]**	**Elevation [Degree]**	**World rain zone map of ITU-R**	
			Zone	**Rain intensity for 0.01%**
Ulaanbaatar	1429	34.5^0	E	22 mm/hr.
Khuvsgul	1301	31.6^0	E	22 mm/hr.
Bayan-Ulgii	1715	28^0	E	22 mm/hr.
Umnugovi	1263	40^0	A	8 mm/hr.
Dornod	713.2	35^0	E	22 mm/hr.

As shown in Table. III, Dornod province is located minimum altitude and Bayan-Ulgii province is maximum altitude above sea altitude. For elevation angle, Dornod and Umnu-Govi provinces are shown better characteristic than others.

Values for the coefficients k and α are determined as functions of frequency, f (GHz), in the range from 1 to 1 000 GHz by ITU-R P.838-3. These values were selected to use in calculation from ITU-R P.838-3.

Table 4: Frequency-dependent coefficients for estimating specific rain attenuation

Frequency GHz	**$K_{(H)}$**	**$\alpha_{(H)}$**	**$K_{(V)}$**	**$\alpha_{(V)}$**
1	0.0000259	0.9691	0.0000308	0.8592
4	0.0001071	1.6009	0.0002461	1.2476
6	0.0007056	1.5900	0.0004878	1.5728
12	0.02386	1.1825	0.02455	1.1216
18	0.07078	1.0818	0.07708	1.0025
26	0.1724	0.9884	0.1669	0.9421
40	0.4431	0.8673	0.4274	0.8421

For linear and circular polarization, and for all path geometries, the coefficients can be calculated from the values given by the following equations [11].

$$k = [k_H + k_V + (k_H - k_V)\cos^2\theta \cos 2\tau]/2 \quad (4.12)$$

$$\alpha = \frac{[k_H\alpha_H + k_V\alpha_V + (k_H\alpha_H - k_V\alpha_V)\cos^2\theta \cos 2\tau]}{2k} \quad (4.13)$$

- $k_{(V)}$ and $\alpha_{(V)}$ – coefficient of vertical polarization.
- $k_{(H)}$ and $\alpha_{(H)}$ – coefficient of horizontal polarization.

Where (τ) is the polarization tilt relative to the horizontal and θ is the path elevation angle. The polarization tilt angle $\tau = 90^0$ for vertical polarization, and $\tau = 0^0$ for horizontal polarization while circular polarization is given $\tau = 45^0$.

As planning, main hub earth station will be established in Ulaanbaatar, Mongolia. Hence we calculated rain attenuation on based three kind of polarization to choice Ulaanbaatar. Comparative result is shown in Table. V.

Table 5: Comparative estimated result of polarizations for c, ku, ka bands in ulaanbaatar, mongolia

Satellite position		113.6^0 E		
Site position		Ulaanbaatar		
Altitude of sea		1428m		
Elevation angle		34.5^0		
Rain-(0.01)		22 mm/hr.		
Polarization		Rain fall intensity-(0.01%)		
Frequency		Horizontal	Circular	Vertical
C Band	4GHz	0.0131	0.0116	0.0115
	6GHz	0.0908	0.0796	0.0683
Ku Band	12GHz	0.8988	0.8509	0.8064
	18GHz	1.9497	1.8431	1.7493
Ka Band	26GHz	3.5601	3.3561	3.1599
	40GHz	6.354	6.1152	5.8807

These results are shown very approximate values. Circular polarization is commonly used in satellite communication. Therefore, these results of calculated on based circular polarization will be used directly in the next calculations.

In this paper, we selected one province from each regional to calculate rain attenuation by ITU-R model on based uplink and downlink of C bands, Ku bands, and Ka bands at space position 113.6 E. Estimated result is shown in Table. VI and Table. VII.

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Table 6: Estimated result of rain attenuation for downlink frequency

Satellite position-113.6 E					
Rain attenuation for 1.0, o.1, 0.01, 0.001 % of year annual					
Regions	**Zone**	**Rain intensity**	**Frequency-Downlink**		
			4 GHz	**12 GHz**	**26 GHz**
Rain attenuation for 1.0 % of year annual-[dB]					
Central zone	A	0.6	0.00026	0.0396	0.305
North zone	B	0.6	0.00038	0.0582	0,449
West zone	C	0.6	0.0003	0.0462	0.356
South zone	D	0.1	0.000021	0.0047	0.0503
East zone	E	0.6	0.00037	0.0563	0.434
Rain attenuation for 0.1 % of year annual-[dB]					
Central zone	A	6	0.0058	0.554	2.78
North zone	B	6	0.0085	0.809	4.06
West zone	C	6	0.0068	0.644	3.24
South zone	D	2	0.0012	0.145	0.896
East zone	E	6	0.0082	0.784	3.94
Rain attenuation for 0.01 % of year annual-[dB]					
Central zone	A	22	0.031	2.262	8.92
North zone	B	22	0.043	3.172	12.51
West zone	C	22	0.035	2.586	10.19
South zone	D	8	0.0074	0.662	3.152
East zone	E	22	0.042	3.097	12.22
Rain attenuation for 0.001 % of year annual-[dB]					
Central zone	A	70	0.018	7.65	24.34
North zone	B	70	0.026	10.24	32.56
West zone	C	70	0.021	8.565	27.27
South zone	D	22	0.0346	1.191	7.538
East zone	E	70	0.025	10.09	32.08

Calculated result was shown rain attenuation by 1.0, 0.1, 0.01, and 0.001% of year annual for downlink in Table. VI.

Table 7: Estimated result of rain attenuation for uplink frequency

Satellite position-113.6 E					
Rain attenuation for 1.0, o.1, 0.01, 0.001 % of year annual					
Regions	**Zone**	**Rain intensity**	**Frequency-Uplink**		
			6 GHz	**18 GHz**	**40 GHz**
Rain attenuation for 1.0 % of year annual-[dB]					
Central zone	A	0.6	0.0008	0.128	0.828
North zone	B	0.6	0,0012	0.188	1.219
West zone	C	0.6	0.0009	0.149	0.967
South zone	D	0.1	0,000042	0,018	0.166
East zone	E	0.6	0.00111	0.182	1.179
Rain attenuation for 0.1 % of year annual-[dB]					
Central zone	A	6	0.0296	1.385	5.85
North zone	B	6	0.0433	2.026	8.55
West zone	C	6	0.034	1.613	6.81
South zone	D	2	0.0048	0.411	2.123
East zone	E	6	0.0419	1.962	8.28
Rain attenuation for 0.01 % of year annual-[dB]					
Central zone	A	22	0.212	4.901	16.3
North zone	B	22	0.297	6.871	22.8
West zone	C	22	0.242	5.601	18.58
South zone	D	8	0.0401	1.605	6.424

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East zone	E	22	0.29	6.709	22.6
Rain attenuation for 0.001 % of year annual-[dB]					
Central zone	A	70	1.182	14.575	39.01
North zone	B	70	1.581	19.502	52.20
West zone	C	70	1.323	16.314	43.67
South zone	D	22	0.179	4.14	15.26
East zone	E	70	1.558	19.212	51.42

As shown in Table. VI and Table. VII, South Zone-D is including Umnugovi province is shown better characteristic with compare other provinces by rain attenuation both of downlink and uplink for Mongolia.

Table 8: Comparative study of rain attennuation.

Rain attenuation for 0.01 % of year annual-[dB]					
Nigeria-Tropical climate & rain season		**Malaysia-Tropical climate with rain season & humidity sea**		**Mongolia-Extreme continental climate without rain season**	
Frequency [GHz]	**[dB]**	**Frequency [GHz]**	**[dB]**	**Frequency [GHz]**	**[dB]**
11	12.76	C	3.42	6	0.212
20	40.39	X	47.48	18	4.901
40	112.35	Ku	102.62	40	16.3

C. Result of section:

In this section, it was used ITU rain prediction model to calculate attenuation in Mongolia based on meteorological statistic data of ITU.

It was used rain height model was defined by ITU-R P.839-3, and specific attenuation coefficient are computed by ITU-R P.838-3, and used rain intensity by ITU-R PN.837-1 model.

By the resulting of Table. VIII, rain attenuation is high atmosphere effect but this high effect is shown more possible condition in Mongolia to compare the countries with tropical climate and rain season, heavy rain as well as located near and humidity sea.

It has presented result of rain at by theoretical equations, figure, and tables. These results are shown that rain attenuation was proportional to some parameters.

VII. CALCULATION OF CLOUD ATTENUATION, ITS METHODOLOGY IN MONGOLIA

Clouds are in the troposphere and consist of liquid water droplets of less than 0.1 mm diameter. The water content ranges from 0.05 to 2g/m^3 [15].

Although cloud attenuation is lower than rain attenuation. It becomes important as clouds are present most of time, while the presence of rain is less than 5-8% of the time.

A. Cloud attenuation calculation in Mongolia

The cloud attenuation is a function of frequency and elevation ange. It increases with increasing frequency and decreasing and decreasing elevation angle. The total attenuation in the clouds is given by (Ippolito, 1999)

$$A_r = \frac{Lk_c}{\sin\theta}\ [dB] \quad (5.1)$$

Where;

- L is the total columnar content of water (kg/m^2)
- k_c is the specific attenuation coefficient (dB/km)/(g/m^3)
- θ is the elevation angle in the range of 10^0-90^0

The values of kc for different frequencies and different temperatures are available from ITU-R (1977) and are shown in Fig. 4, as follows:

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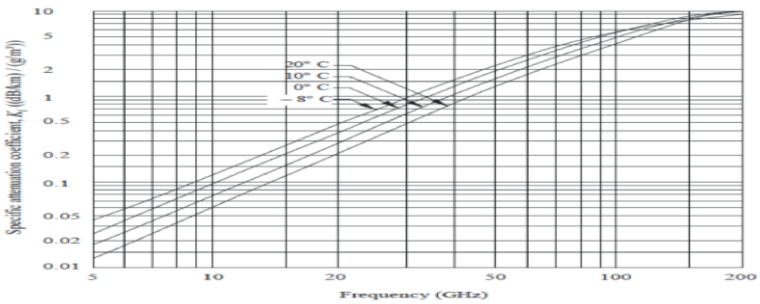

Fig. 4: Specific attenuation coefficient for clouds

B. Methodology of Cloud calculation.

Mongolia is landlocked country and located so far from sea and ocean. It will be calculated by these data that is minimum value - (0.5 g/m^3) columnar water content of clouds and elevation angle of antenna from 28^0 to 40^0 in earth station in each provinces of Mongolia [15].

Specific attenuation coefficients are:

- Cloud temperature (-80) C: Uplink C band-0.06, Ku band-0.27, Ka-1.5
- Cloud temperature (100) C: Uplink C band-0.03, Ku band-0.22, Ka-1.2
- Cloud temperature (200) C: Uplink C band-0.018, Ku band-0.2, Ka-0.8

The cloud attenuation was estimated by mathematical model in selected province Dornod.

In order to develop cloud attenuation model, we used Ippolito`s cloud attenuation formula, specific attenuation coefficient for clouds by ITU-R model, and elevation angle from from 28^0 to 40^0 degree, operation frequencies including uplink C band, Ku-band and Ka-band and cloud temperature is (-8^0) C degree, 10^0 C degree and 20^0 C degree [16].

C. *Uplink-Cloud temperature (-8^0) degree*

C-band: 6 GHz, cloud temperature (-8^0), Specific attenuation coefficient-0.06, water content 0.5 g/m^3.

$$A_r = \frac{Lk_c}{\sin\theta} = \frac{0.5 * 0.06}{\sin 35^0} = 0.0523\ dB/km$$

K$_u$-band: 18 GHz, cloud temperature (-8^0), Specific attenuation coefficient-0.27, water content 0.5 g/m^3.

$$A_r = \frac{Lk_c}{\sin\theta} = \frac{0.5 * 0.27}{\sin 35^0} = 0.2354\ dB/km$$

K$_a$-band: 40 GHz, cloud temperature (-8^0), Specific attenuation coefficient-1.5, water content 0.5 g/m^3.

$$A_r = \frac{Lk_c}{\sin\theta} = \frac{0.5 * 1.5}{\sin 35^0} = 1.3076\ dB/km$$

Table 9: Estimated result of cloud attenuation for uplink frequency

Satellite position-113.6 E					
Cloud attenuation for -8^0,10^0, 20^0 degree [dB]					
Province	Elevation	Azimuth	Frequency-Downlink		
			6 GHz	18 GHz	40 GHz
Cloud attenuation for -8^0 C- [dB]					
Ulaanbaatar	34.5	170.4	0.0529	0.2383	1.324
Khuvsgul	31.6	162.6	0.0566	0.2547	1.4153
Bayan-Ulgii	28	150	0.06	0.27	1.5
Umnugovi	40	166.8	0.0477	0.2145	1.1917
Dornod	35	181.26	0.0523	0.2354	1.3076
Cloud attenuation for 10^0 C- [dB]					
Ulaanbaatar	34.5	170.4	0.0265	0.1942	1.059
Khuvsgul	31.6	162.6	0.0283	0.2076	1.132
Bayan-Ulgii	28	150	0.003	0.22	1.2
Umnugovi	40	166.8	0.0238	0.1748	0.953
Dornod	35	181.26			
Cloud attenuation for 20^0 C- [dB]					
Ulaanbaatar	34.5	170.4	0.0159	0.176	0.706
Khuvsgul	31.6	162.6	0.017	0.189	0.755
Bayan-Ulgii	28	150	0.018	0.2	0.8
Umnugovi	40	166.8	0.0143	0.159	0.636
Dornod	35	181.26	0.0157	0.174	0.697

Cloud attenuation was calculated by three kind of operation frequency in different cloud temperatures for each province of Mongolia.

By the results have shown that the cloud attenuation was proportional to some parameters.

When operation frequency is increased cloud attenuation is also increased and for temperature decreased attenuation is increased, as well as elevation an angle of antenna is decreased attenuation is increased etc.

Table 10: Estimated result of cloud attenuation for downlink frequency

Satellite position-113.6 E					
Cloud attenuation for -8⁰,10⁰, 20⁰ degree [dB]					
Province	Elevation	Azimuth	Frequency-Downlink		
			4 GHz	12 GHz	26 GHz
Cloud attenuation for -8⁰ C- [dB]					
Ulaanbaatar	34.5	170.4	0.0353	0.1324	0.6179
Khuvsgul	31.6	162.6	0.0377	0.1415	0.6604
Bayan-Ulgii	28	150	0.04	0.15	0.7
Umnugovi	40	166.8	0.0317	0.1191	0.5561
Dornod	35	181.26	0.0348	0.131	0.6102
Cloud attenuation for 10⁰ C- [dB]					
Ulaanbaatar	34.5	170.4	0.00971	0.0882	0.0438
Khuvsgul	31.6	162.6	0.0103	0.0943	0.4717
Bayan-Ulgii	28	150	0.011	0.1	0.5
Umnugovi	40	166.8	0.00874	0.0794	0.3972
Dornod	35	181.26	0.00958	0.0871	0.4358
Cloud attenuation for 20⁰ C- [dB]					
Ulaanbaatar	34.5	170.4	0.0159	0.176	0.3531
Khuvsgul	31.6	162.6	0.0141	0.066	0.3774
Bayan-Ulgii	28	150	0.015	0.07	0.4
Umnugovi	40	166.8	0.0119	0.0556	0.3178
Dornod	35	181.26	0.0130	0.061	0.3486

This section provides the brief overview of cloud attenuation, comparative studies of cloud attenuation model and estimation of cloud attenuation in Mongolia.

Although estimated result of cloud attenuation is low in Mongolia, it must be considered for the reliable satellite communication systems.

VIII. COMPARATIVE ANALYSIS OF ESTIMATED RESULT OF RAIN AND CLOUD ATTENUATION

It was selected uplink frequency to make comparative analysis by estimated results of cloud and rain attenuation.

Although cloud attenuation is lower than rain attenuation. It becomes important as clouds are present most of time, while the presence of rain is less than 5-8% of the time.

Table 11: Comparative analysis of cloud and rain attenuation for uplink frequency

Indicator	Satellite position-113.6 E					
	Cloud attenuation for -8⁰ C- [dB]			Rain attenuation for 0.01% of year annual		
Provinces	6 GHz	18 GHz	40 GHz	6 GHz	18 GHz	40 GHz
Ulaanbaatar	0.0529	0.2383	1.324	0.212	4.901	16.3
Khuvsgul	0.0566	0.2547	1.4153	0.297	6.871	22.8
Bayan-Ulgii	0.06	0.27	1.5	0.242	5.601	18.58
Umnugovi	0.0477	0.2145	1.1917	0.0401	1.605	6.424
Dornod	0.0523	0.2354	1.3076	0.29	6.709	22.6

When we conducted a comparative study of cloud attenuation and rain attenuation, we considered the calculated results of 0.01 percent of the annual year for the rain attenuation calculation and for cloud attenuation by using calculated result of -8 degrees.

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Both of result of rain and cloud was calculated on the C, Ku, and Ka frequencies of uplink.

IX. CONCLUSIONS

Currently in Mongolia has not own satellite in the space segment, number of Mongolian organization and company are using another country`s communication satellites via leased channel for various purposes.

Mongolian Government planned to lunch and use "National satellite" including communication service satellite in GEO orbit in 2030.

In this paper, we have determined the geometrical parameters of national satellite 113.6 E as well calculation rain and cloud attenuation by using both of mathematical model and ITU-R model to make comparative analysis and defined the following conclusions.

- Advantage of research work is determined the geometry calculation, rain and cloud attenuation of the national satellite that will be launched to position 113.6E in space segment.
- During the study work, selected the frequency range that uplink and downlink of C band, Ku band, and Ka band to estimated rain and cloud attenuation to show comparative study.
- Novelty is to Rain and Cloud attenuation can also be calculated for various location of Mongolia with these models using real time data and the result will be useful for future satellite communications in rainy and cloudy conditions.

When we propose the satellite networks for Mongolia, the operational scenarios during the raining condition have to consider to mitigate the rainfall effect.

If a satellite link is to be maintained during a rainfall, it is necessary that extra power to be transmitted to overcome the degradation induced by rain. Or other signal transmission mechanisms such as modulation index change, or changing to lower coding gain.

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