Development of a prediction model for Atmospheric Scintilla-tions on earth –space Ka band link in Indian Climate

R.Prabhakar, T.V.Ramana

Abstract--- To develop an improved new prediction model form measurement of tropospheric scintillations for Indian Climate of satellite ka band signals which is used in adaptive link control in the design of satellite communication system. Because in Indian climate will be tropical and changing seasonally. Due to small variations occurred in refractive index and rapid signal fluctuations occurred in the signal amplitude and angle of the signal in turbulent layer when the received signals passing through it, then .This is called scintillation. The scintillations more significant in ka band signals. Propagation experiment carried out at The SAC of ISRO on Ka-band over India. To this purpose, the GSAT-4 satellite will board two antennas at 30.5GHz and 20.2GHz in linear polarization

Keywords: Refractive Index, Monthly averaged pressure, Monthly averaged Temperature, Relative Humidity and Height, Ka band, Tropospheric scintillations.

INTRODUCTION

Scintillations

Solar Energy from sun heats up surface of the earth results in turbulent at the boundary layer causes small scale fluctuations in radio refractive index**,** when the received satellite signals are passing through the turbulent layer ,fast fluctuations occurred in radio refractive index fluctuations occurred within the 4km range called troposphere scintillations. These fluctuations in signal amplitude more significant in small aperture antennas and Ka band frequency for low availability SC Systems.

Scintillations caused by

Gradients and Convective heating produces turbulence ,scatterers random distribution produces pure scattering and rain drop size distribution of variations produces apparent scintillations.

The scope of Satellite Communication will continue at a rapid pace over the globe in the years to come. Thus there is a need to expand Satellite Communications to higher frequency bands. There is a worldwide interest, including for ISRO (the Indian Space Research Organisation), in using the Ka Band in future Satellite Communication Systems. The Ka band frequency advantages for SC than C and Ku bands. The equipment size and interference reduced by spectrum availability to improve service quality. Deterministical and statistical models are available. Physical descriptions for deterministical phenomenon, but statistical models are practically used. the effect of the Earth's atmosphere on 30/20 GHz frequencies, the performance of statistical models over region of interest need to be tested and the most accurate ones should be recommended for use. An opportunity has been proposed by SAC of ISRO to carry out a propagation experiment at Ka-band over India [3]. To this purpose, the GSAT-4 satellite will board two propagation antennas at 30.5GHz and 20.2GHz in linear polarization. For performance measurements, to install equipments are Earth stations, radiometers, microwave radars, meteorological sensors to perform the measurements, and to process and analyze the data. This new propagation experiment is a nice opportunity to test both statistical prediction methods. The main outcome of data collection and analysis, will be to develop/recommend a technique for fading prediction of radio wave propagation in Ka Band over Indian tropical areas and to develop suitable model. The major objectives of conducting Ka band propagation experiment are: 1.Getting experimental time series of tropospheric impairments in tropical regions at Ka band for new Satcom air interface performances assessment. 2. Study of tropospheric scintillation at Ka band. 3.Getting meteorological data in tropical region and compare with prediction models

The main outcome of the Ka band propagation experiment will be: ƒ Validation and selection of a suitable over Indian Tropical region. ƒ Assessment of performance, based on validation of frequency scaling technique. ƒ Selection and validation of suitable tropospheric scintillation prediction model.

India is a unique country with great diversity of geographic features, rainfall and climate. For the site selection the following criteria were considered:

a)Different meteorological conditions
b) Different geographical regions
c) Different elevation angles to satellite

Revised Manuscript Received on March 10, 2019.

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Table 1: Specifications Of Ka-Band Beacon Payload In Gsat-4

	Parameter	Unit	Specification	
			30 GHz	20 GHz
1	Transmit Frequency	GHz	30.5	20.2
2	Transmit Polarization (Change polarization on command)	-	Linear H & V	Linear H & V
3	Cross Polar Isolation	dB	30.0	30.0
4	Transmit EIRP	dBW	24.0	24.0
5	Frequency Stability over operating temperature over Design Life	Ppm	±1.0 ± 7.0	±1.0 ±7.0
6	Spurious Output at Tx Antenna in any 4 KHz band in any 1 MHz band	dBW	 -60 -55	 -60 -55

Ground segment of the GSAT-4 Propagation Experiment

Meteorological and Ka band data collection equipment will be installed at selected site in India. These equipments will collect meteorological data from different sites having varying characteristics. Beacon receivers to be used for attenuation measurements at Ka band by all the experimental partners are based on a common design and have a common data interface. All the meteorological equipment at all the sites are identical. Sites will be configured with equipment: Ka band Beacon Receiver(s), Radiometers, Disdrometer, Microwave rain radar, Tipping Bucket rain gauge, Automatic Weather Stations (AWS), Data Loggers.

Beacon Earth station

The Earth station will measure the receiver power from the satellite beacon transmitter at 20.2 and 30.5 GHz. And constituted with 120 cm diameter antenna which provide about 40-45 dBi. The received signals at 20.2 and 30.5 GHz are down converted to 10 MHz and 20 MHz respectively, with 300 kHz bandwidth by a dual stage frequency conversion. Then the signal is processed to produce differential In-phase (I)and Quadrature(Q) signals.The 'I' & 'Q' signals are used for determining the satellite beacon signal amplitude and phase using FFT.The Beacon Receivers allowed dynamic ranges to be better than 25 dB and offer an accuracy of 0.5 dB. The data will be measured at sampling rates between 5 and 20 Hz.

The Earth station is a dual frequency dual polarization equipment. It will measure in both vertical and horizontal polarizations at a maximum rate of 20 Hz.The Beacon receiver consists of two separate antennas for receiving 20.2 and 30.5 GHz beacon signals in both polarizations. Two separate RF blocks are used to down convert Vertical and Horizontal signals.

Fig.1 : CNES dual frequency single polarization outdoor Earth station

Link Budget

Table 2: Example Of Link Budget For An Earth Station Located At Sac-Isro Premlises

Parameters	20.2 GHz	30.5 GHz
Satellite EIRP	24 dBW	24 Dbw
Total clear sky losses	211 dB	214 dB
Power at Antenna feed	-187 dB	-190 dB
Antenna gain	46 dBi	48 dBi
Received power at clear sky	-111 dBm	-112 dBm
Threshold signal power	-148 dBm	-148 dBm
Figure of merit G/T	17 DBK^{-1}	19 DBK^{-1}
Resolution Bandwidth	30 Hz	30 Hz
Received SNR	44 dB	43 dB
Threshold SNR	10 dB	10 dB
Maximum dynamic range	34 dB	33 dB

New Prediction Model

The proposed Tropospheric scintillation prediction model used for calculating the standard deviation of signal fluctuation due to scintillation. This model uses input of the wet term of earth refractivity *wet* N, regarding relative humidity and temperature, averaged six months.

Atmospheric Refractive Index:

Satellite Signal passing through free space turbulent mixing of temperature, humidity and water vapour pressure on ka band frequency .Then radio refractivity N is

N=(m-1)x10^6(ppm)

The total radio refractivity contains wet term w and clear dry air term N, Water vapour contribution is

Nw=373e/T^2(PPm)

Nd=77.6P/T(PPm)

Total refractivity is given by N=776/T(P+4810e/T)

Here PPm parts per million,T is Temparature in Kelvin,P-pressure in mbarwater vapour pressure e,The height with vertical profile relationship is given by exponentially decreasing above sea level (km) as N(h)315e-(h/7.36),In practice radio refractivity randomly fluctuating in space and time.

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Satellite Communication Systems at HFs and Low elevation angles:

Geostationary satellites at high latitude Ka band links beyond 81.34° not visible from subsatellite point in longitude or latitude

At this visible portion of elevation angle decreases from zenith subsatellite point to zero circular fringe for path elevation to satellite from earth station of longitude at 10° from subsatellite point and latitude from 0 to 81.34°. The maximum elevation angle 11.5° at latitude of 70° and decreased to 1.33° at latitude of 80°. Large scale refractive index and scintillations in atmosphere gives to ducting and ray bending produce fades 20dBs. Commercial systems uses 5° is the minimum elevation angle.

Table.1.Spacefications

Station Name	Monthly Avg. Temparature(C)	Monthly Avg. Relative Humidity(%)	Avg. Pressure(hPa)	Lat. ○ N	Long. ○ E	Elev. angle (Deg)
Hyderabad	24.75	52.5	897	17° 37'	78° 43'	64.67°

Standard Deviation:

σ = σref f^7/12 g(x) /(sinΘ)^2

where, σref reference threshould standard level,
g(x)-antenna averaging factor,
f-carrier frequency in GHz.
The time % factor for 0.001<p<50.
Fade depth value is As(p)=σ.a(p)

RESULTS

	A	B	C	D
1	Equation	y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2		
2	Adj. R-Square	-0.42857		
3			Value	Standard Error
4	amplitude scintillation	y0	0.16636	0.05625
5	amplitude scintillation	xc	-1.87196E12	--
6	amplitude scintillation	w	0.01275	--
7	amplitude scintillation	A	-4.44252	--
8	amplitude scintillation	sigma	0.00637	
9	amplitude scintillation	FWHM	0.01501	
10	amplitude scintillation	Height	-278.02182	

Table.3.Amplitude scintillation Exponential decreasing report

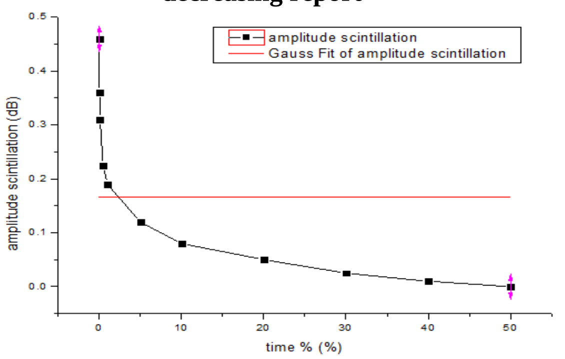

Fig.2.Amplitude scintillation Exponential decreasing Gauss curve fit

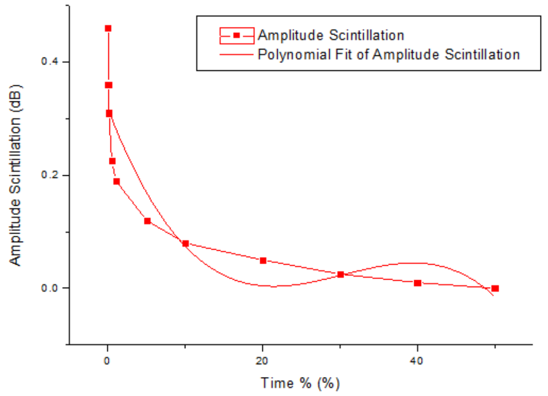

Fig.3 .Amplitude Scintillation with 3rd Order Polynomial Fit

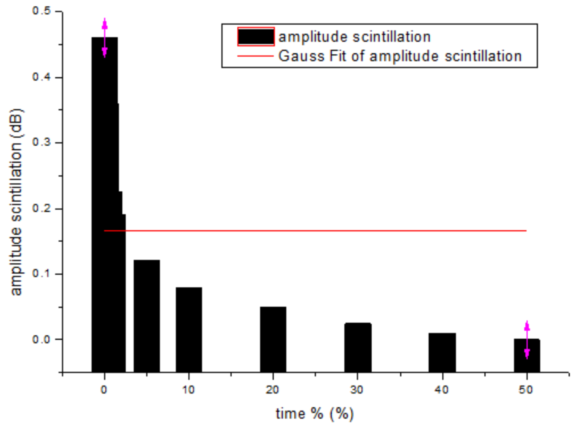

Fig.4.Amplitude Scintillation with Histogram representation

		Value	Standard Error
amplitude scintillation	y0	0.16636	0.05625
	xc	-1.87196E12	--
	w	0.01275	--
	A	-4.44252	--
	sigma	0.00637	
	FWHM	0.01501	
	Height	-278.02182	

Table.4.Nonlinear curve fitting for amplitude scintillation

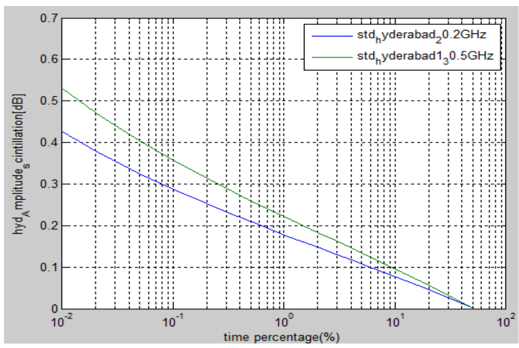

Fig.5..Amplitude scintillations with respect to time % factor

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	A(X)	B(Y)
Long Name	time %	amplitude scintil
Units	%	dB
Comments		
1	0.01	0.46
2	0.05	0.36
3	0.1	0.31
4	0.5	0.225
5	1	0.19
6	5	0.12
7	10	0.08
8	20	0.05
9	30	0.025
10	40	0.01
11	50	0

Table5: for time % and scintillations

The relationship between Relative humidity and monthly average temperature and Pressure characteristics are plotted for six months recorded data the dce2016 to June 2017 in Hyderabad, India. The amplitude scintillation will be inversely proportional to the amplitude scintillations. The scintillation intensity is observed that 0.00637dB and monthly averaged temperature is inversely proportional to the monthly averaged height of the turbulent layer from the surface of the earth.

Relative humidity is Inversely proportional to the temperature. The measured fades stretch upto .42dB and 0.52dB at 0.01% of time at 20.2GHz, 30.5GHz of frequencies and 1006m of turbulent layers height. The measured enhancements stretch upto 0.1 dB and .52dB at 0.01% of time.The standard error is 0.0525dB,

Refractive Index measured value is 1.0032636 and variations in refractive index is 0.0032616.

CONCLUSION

Developed an improved new prediction model for measured data of tropospheric scintillations on ka band satellite signals in Indian climate which is used in adaptive link control in the design of satellite communication system.

The new prediction of scintillations observed by using Gaussian distribution and third order polynomial fit to the measured values of India's tropical climate. The standard deviation is increased with the increased frequency and decreased elevation angle , is proven with simulation. Statistics were estimated at different attenuated levels ,higher values in ka band. because scintillations effect very strong with high frequency. Small signals wavelength leads more fluactions. The Ka band signal communication link affected strongly by phenomenon of scintillations.

GSAT-4 satellite. This satellite will board two propagation beacons transmitting pure carriers at 20.2 GHz and 30.5 GHz.

The main objective is ka band channel characterization in the different climates of India to be able to improve propagation models for these tropical regions for each experimental location beacon receivers ,multi-frequency radiometers, micro-rain radars, rain gauges, disdrometers and meteorological sensors will be installed. Finally,focuses on the data processing methodology that will be followed to process the raw data measured by the equipment.

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