“DESIGN OF SATELLITE LINKS FOR Ka-BAND NETWORK IN NEPAL”

Presented By

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OBJECTIVE OF THE WORK

- To design Ka-band network links by logically selecting technologies and optimizing scarce resources.

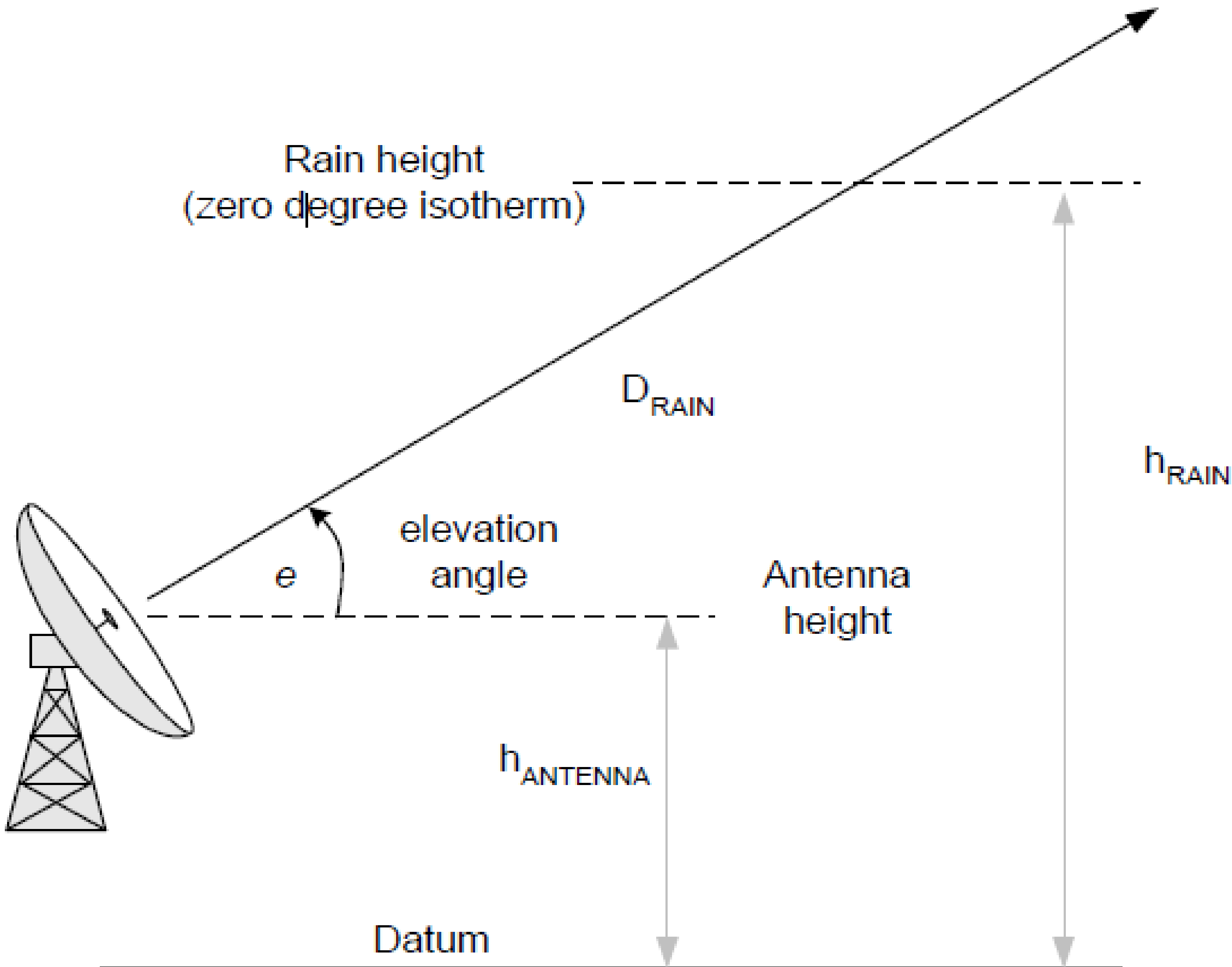
- To depict the simulation studies for linkages between Nepalese site-specific attenuation, resources, geographic plus system attributes and quality parameters.

De-merit of ka-band

:

More susceptible to fading including rain attenuation than other bands like C and Ku.

RAIN ATTENUATION CALCULATION-



STEPS UTILIZED FOR MATLAB PROGRAM GENERATION

- Step 1:Determine the rain height based on latitude.
- Step 2: Compute the slant-path length, L_s.
- Step 3: Calculate the horizontal projection, LG, of the slant-path length.
- Step 4: Obtain the rainfall rate, R0.01, exceeded for 0.01% of an average year.
- Step 5: Obtain the specific attenuation.

- Step 6: Calculate horizontal adjustment factor and Calculate adjusted path length
- Step 7: Calculate the vertical adjustment factor for 0.01% of the time.
- Step 8:Calulate Effective path length
- Step 9 : Calculate rain attenuation at 0.01% of time.

RESULTS:

S.N.	Site Name	Rain Attenuation(in dB) for Uplink	Rain Attenuation(in dB) for Downlink
1	NCIT(Lalitpur)	42.13 dB (p=0.01) (7.2708 dB for 0.5)	33.25 dB(p=0.01) (5.5065 dB for 0.5)
2	Pokhara University(Pokhara)	45.44 dB (p=0.01) (7.8678dB for 0.5)	35.56 dB(p=0.01) (5.9048 dB for 0.5)
3	Transportable Site	-	-

- Note: Basis of ITU new grid based model

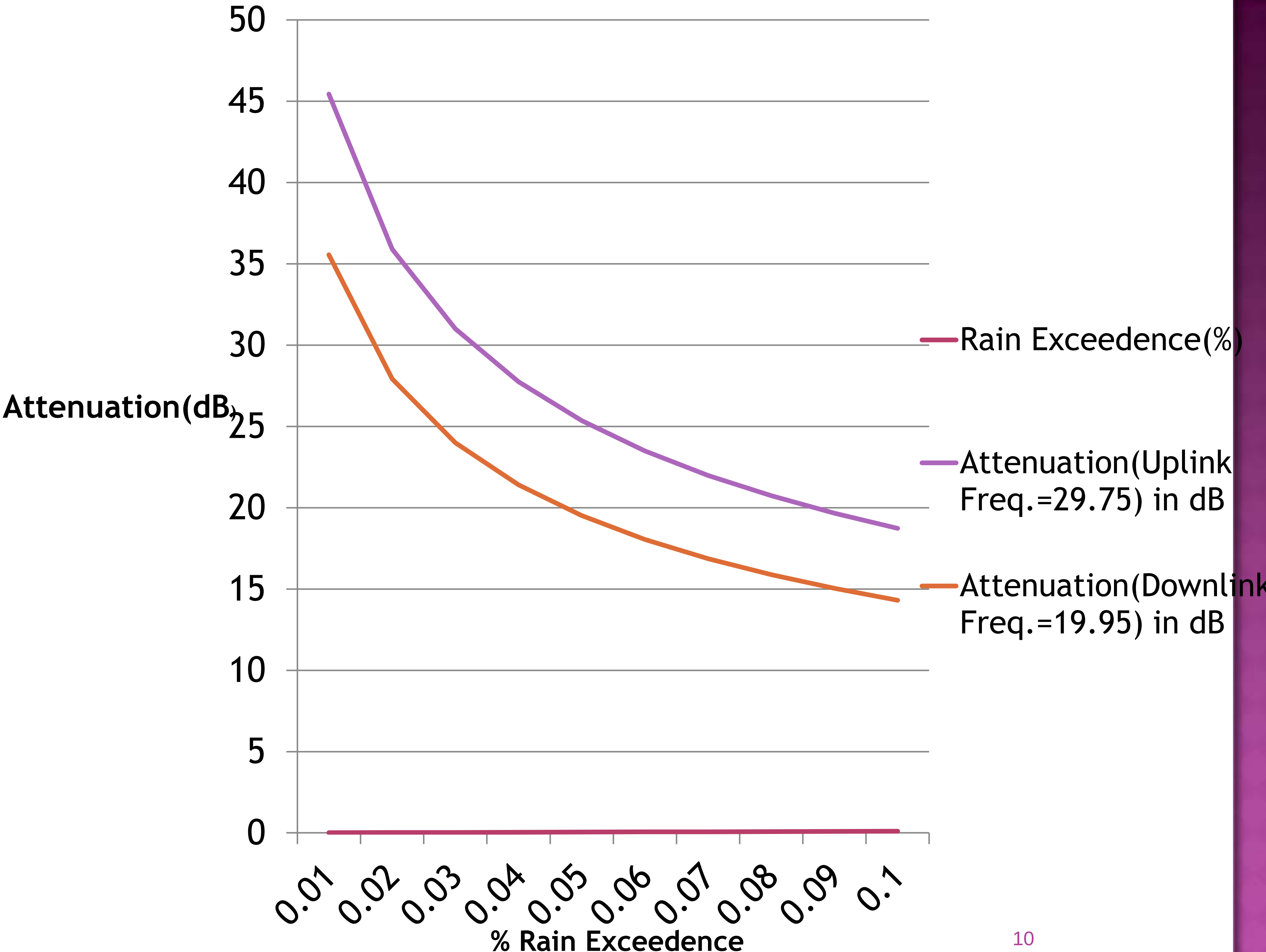
S.N.	Site Name	Latitude	Longitude	Rain rate (mm/hr) at 0.01%
1	NCIT(Lalitpur)	27.6714 °	85.3387 °	46.4764
2	Pokhara University(Pokhara)	28.1453 °	84.0838 °	52.4587
3	Transportable Site	-	-	-

- The rain attenuation varies from location to location depending on the rain rate and other parameters.
- Providing for the large attenuation in satellite links like in case of Pokhara (uplink) can lead to over-design and higher cost.
- Hence accommodation in our case will be made by using a suitable fade mitigation techniques among Uplink Power Control (UPC) , Adaptive Coding and Modulation(ACM) and site diversity or any of their combination.

RAIN EXCEEDENCE VS ATTENUATION AT POKHARA UNIVERSITY

		Pokhara University(Pokhara)	
Rain Exceedence	Availability	Attenuation(Uplink Freq.=29.75)	Attenuation(Downlink Freq.=19.95)
0.01	99.99	45.44	35.56
0.02	99.98	35.9042	27.9157
0.03	99.97	31.0051	23.9995
0.04	99.96	27.7493	21.4116
0.05	99.95	25.3598	19.52
0.06	99.94	23.4989	18.0514
0.07	99.93	21.9908	16.8644
0.08	99.92	20.7333	15.8767
0.09	99.91	19.6618	15.0367
0.1	99.9	18.7333	14.3101

Rain exceedence & Availability -% , Attenuation- dB

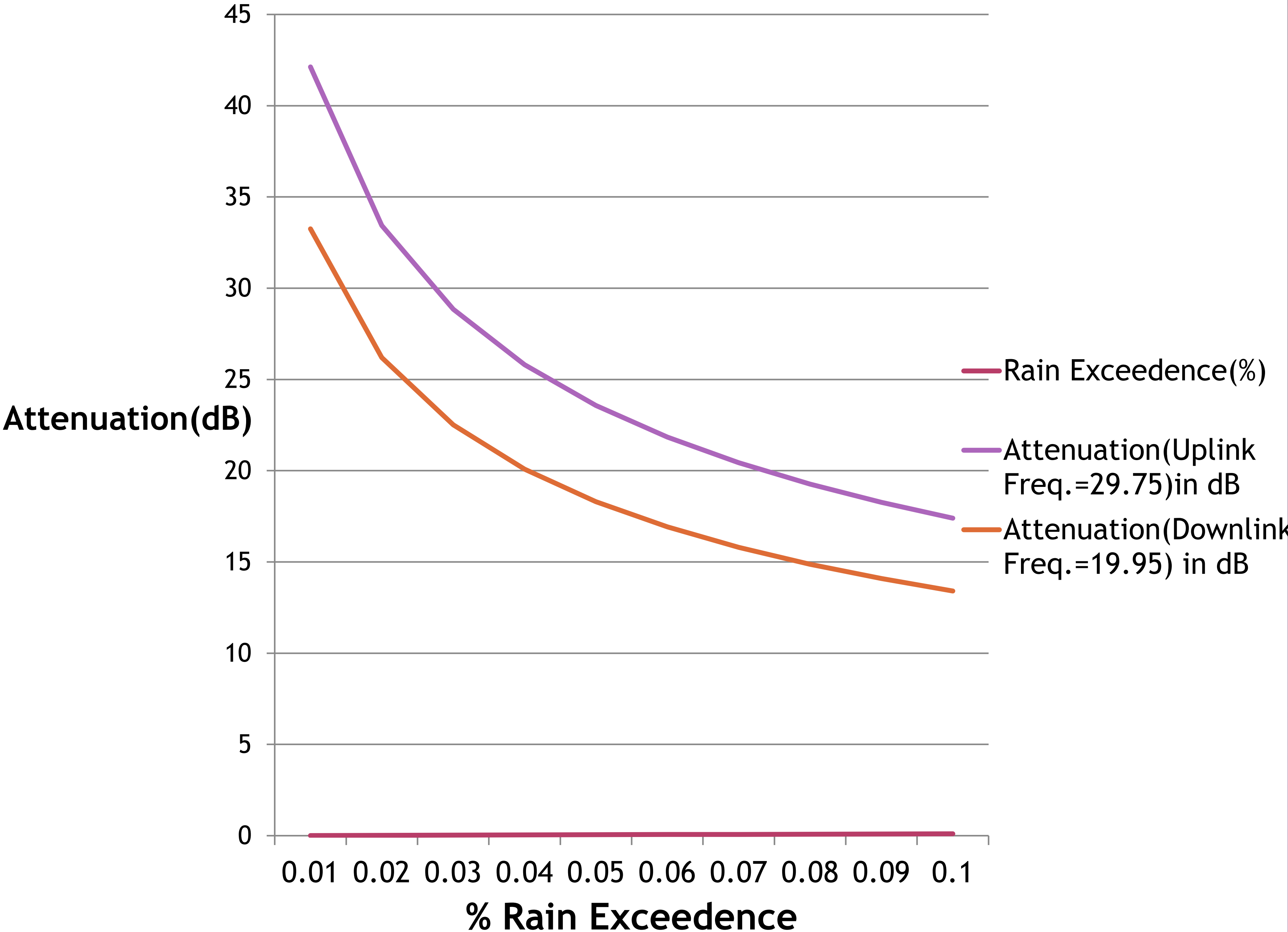


50
45
40
35
30
25
20
15
10
5
0
Attenuation(dB)
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
% Rain Exceedence
Rain Exceedence(%)
Attenuation(Uplink Freq.=29.75) in dB
Attenuation(Downlink Freq.=19.95) in dB

RAIN EXCEEDENCE VS ATTENUATION AT NCIT

		NCIT(Lalitpur)	
Rain Exceedence	Availability	Attenuation(Uplink Freq.=29.75)	Attenuation(Downlink Freq.=19.95)
0.01	99.99	42.13	33.25
0.02	99.98	33.4321	26.2022
0.03	99.97	28.852	22.5154
0.04	99.96	25.8104	20.0802
0.05	99.95	23.5791	18.3008
0.06	99.94	21.8419	16.9197
0.07	99.93	20.4346	15.8036
0.08	99.92	19.2613	14.875
0.09	99.91	18.2617	14.0854
0.1	99.9	17.3956	13.4024

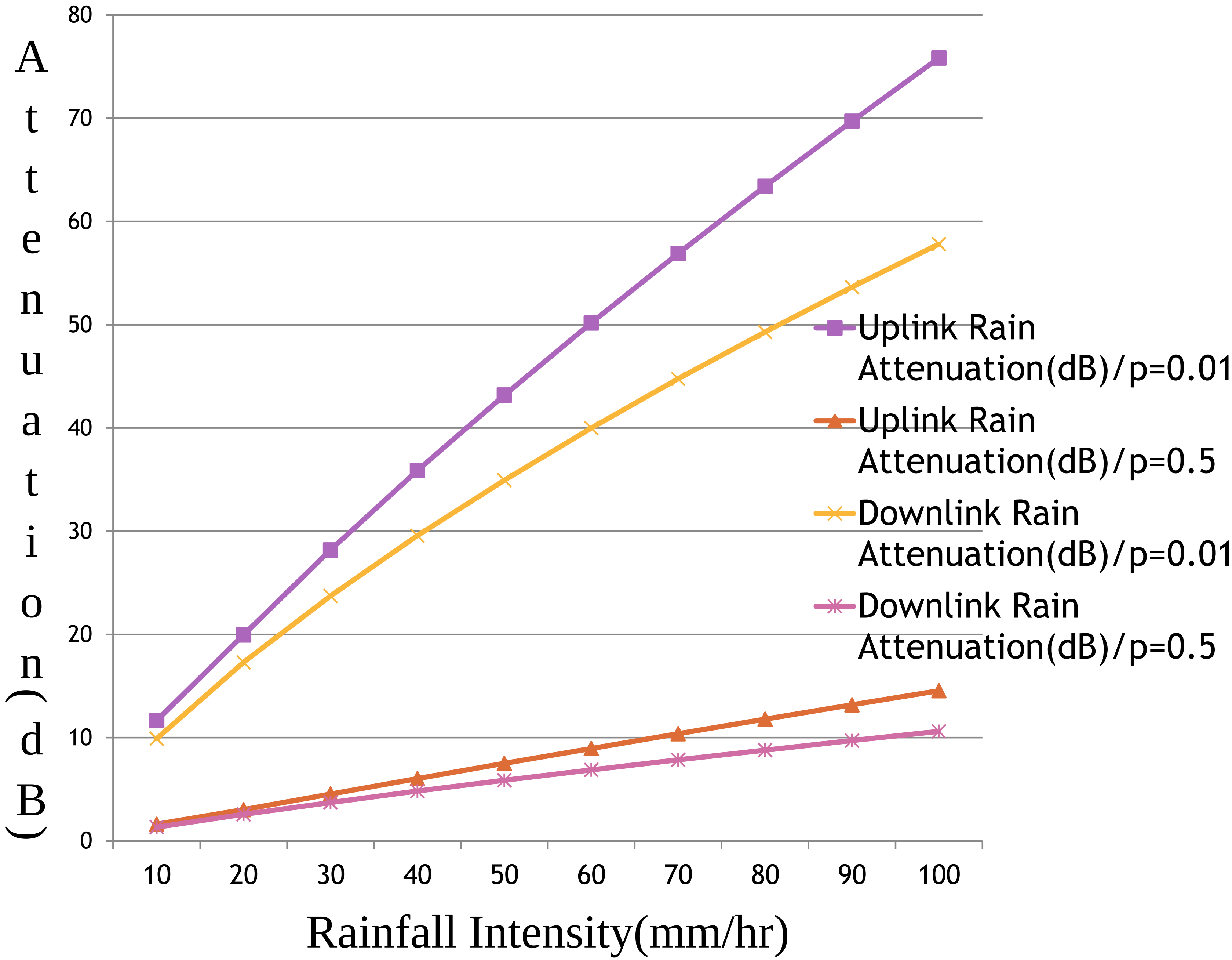
Rain exceedence & Availability -% , Attenuation- dB



45
40
35
30
25
20
15
10
5
0
Attenuation(dB)
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
% Rain Exceedence
Rain Exceedence(%)
Attenuation(Uplink Freq.=29.75)in dB
Attenuation(Downlink Freq.=19.95) in dB

RAINFALL INTENSITY VS ATTENUATION AT DIFFERENT PROBABILITIES FOR BOTH UPLINK AND DOWNLINK

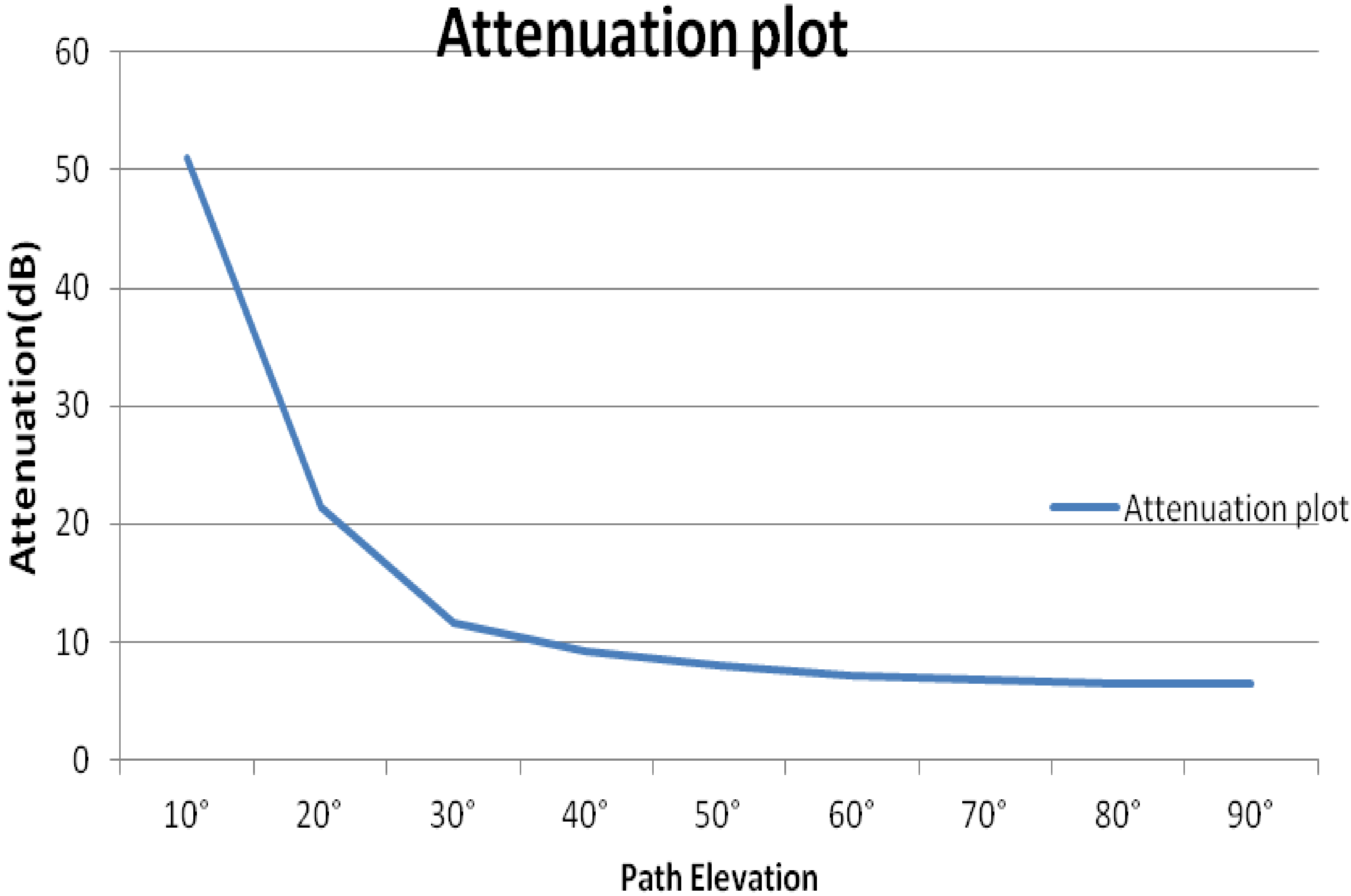
	Uplink Frequency		Downlink Frequency	
Rainfall Intensity(mm/hr)	Uplink Rain Attenuation(dB)/p =0.01	Uplink Rain Attenuation(dB)/ p=0.5	Downlink Rain Attenuation(dB)/p =0.01	Downlink Rain Attenuation(dB)/ p=0.5
10	11.6577	1.6082	9.898	1.3311
20	19.9523	3.0256	17.2937	2.5657
30	28.1783	4.5407	23.7296	3.7221
40	35.8801	6.033	29.5575	4.819
50	43.1877	7.5026	34.9455	5.8679
60	50.1793	8.9505	39.9922	6.8767
70	56.9073	10.3779	44.7623	7.8511
80	63.4098	11.7861	49.3012	8.7955
90	69.7152	13.1762	53.6427	9.7133
100	75.8459	14.5491	57.8125	10.6072



Attenuation(dB)
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Rainfall Intensity(mm/hr)
Uplink Rain Attenuation(dB)/p=0.01
Uplink Rain Attenuation(dB)/p=0.5
Downlink Rain Attenuation(dB)/p=0.01
Downlink Rain Attenuation(dB)/p=0.5

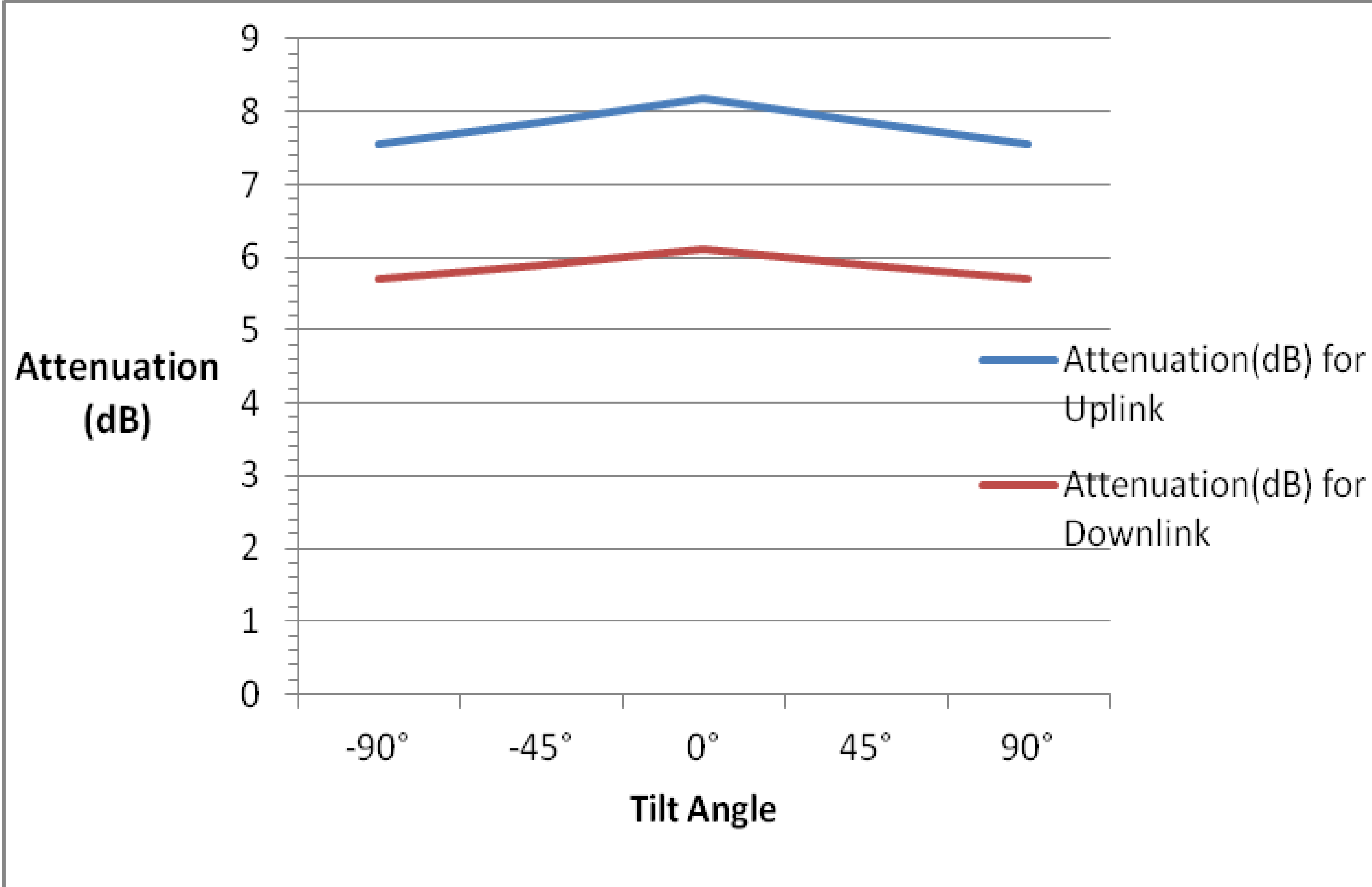
PATH ELEVATION VS ATTENUATION AT POKHARA STATION ON 29.75 GHZ

Path Elevation (Degrees)	Attenuation(dB)- Uplink
10°	51.0398
20°	21.4313
30°	11.6447
40°	9.2456
50°	7.9539
60°	7.2004
70°	6.7579
80°	6.5231
90°	6.4494


Attenuation plot
60
50
40
30
20
10
0
Attenuation(dB)
10°
20°
30°
40°
50°
60°
70°
80°
90°
Path Elevation
Attenuation plot

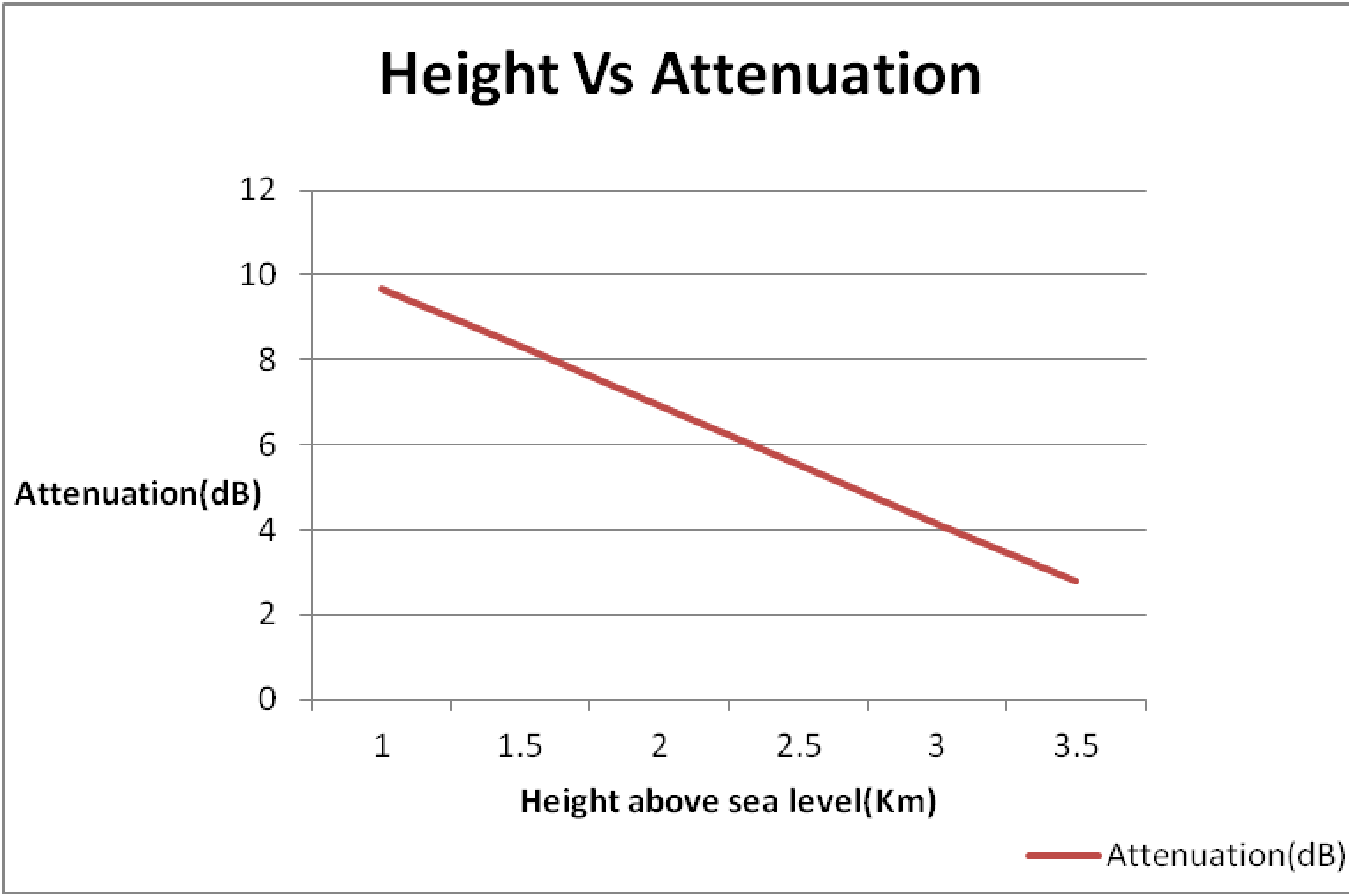
TILT ANGLE VS ATTENUATION FOR POKHARA AND NCIT AT RESPECTIVE ELEVATION ANGLES

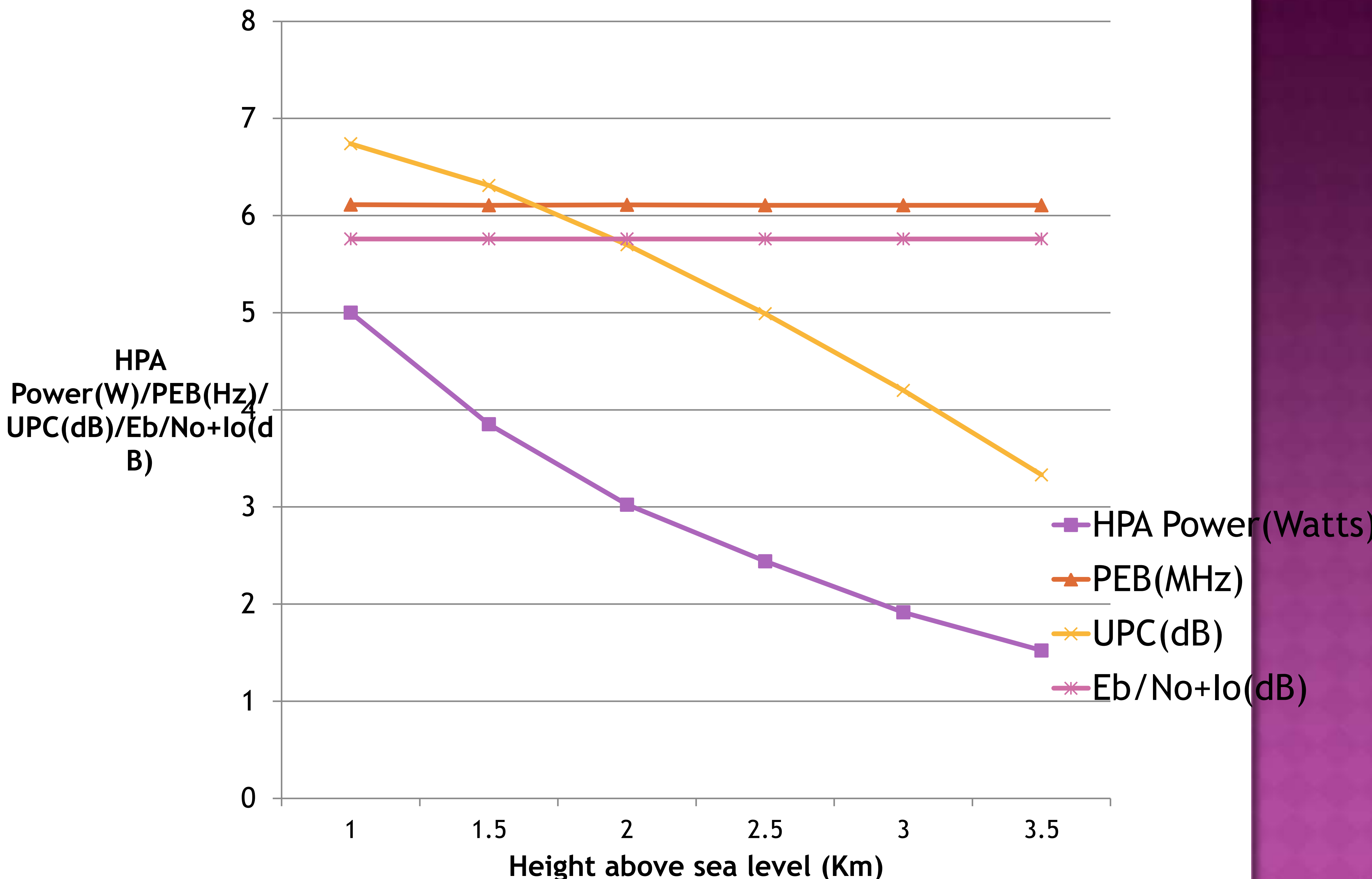
Tilt Angle (Degrees)	Attenuation(dB) for Uplink	Attenuation(dB) for Downlink
-90°	7.5558	5.6941
-45°	7.8678	5.9048
0°	8.1717	6.1087
45°	7.8678	5.9048
90°	7.5558	5.6941



9
8
7
6
5
4
3
2
1
0
Attenuation (dB)
Attenuation(dB) for Uplink
Attenuation(dB) for Downlink
-90°
-45°
0°
45°
90°
Tilt Angle

HEIGHT ABOVE SEA LEVEL VS ATTENUATION




8
7
6
5
4
3
2
1
0
HPA Power(W)/PEB(Hz)/ UPC(dB)/Eb/No+Io(dB)
1
1.5
2
2.5
3
3.5
Height above sea level (Km)
HPA Power(Watts)
PEB(MHz)
UPC(dB)
Eb/No+Io(dB)

LINK BUDGET DESIGN

- Tools & software utilized:

SATMASTER Pro

- Satellite Considered :Spacecom's AMOS-4

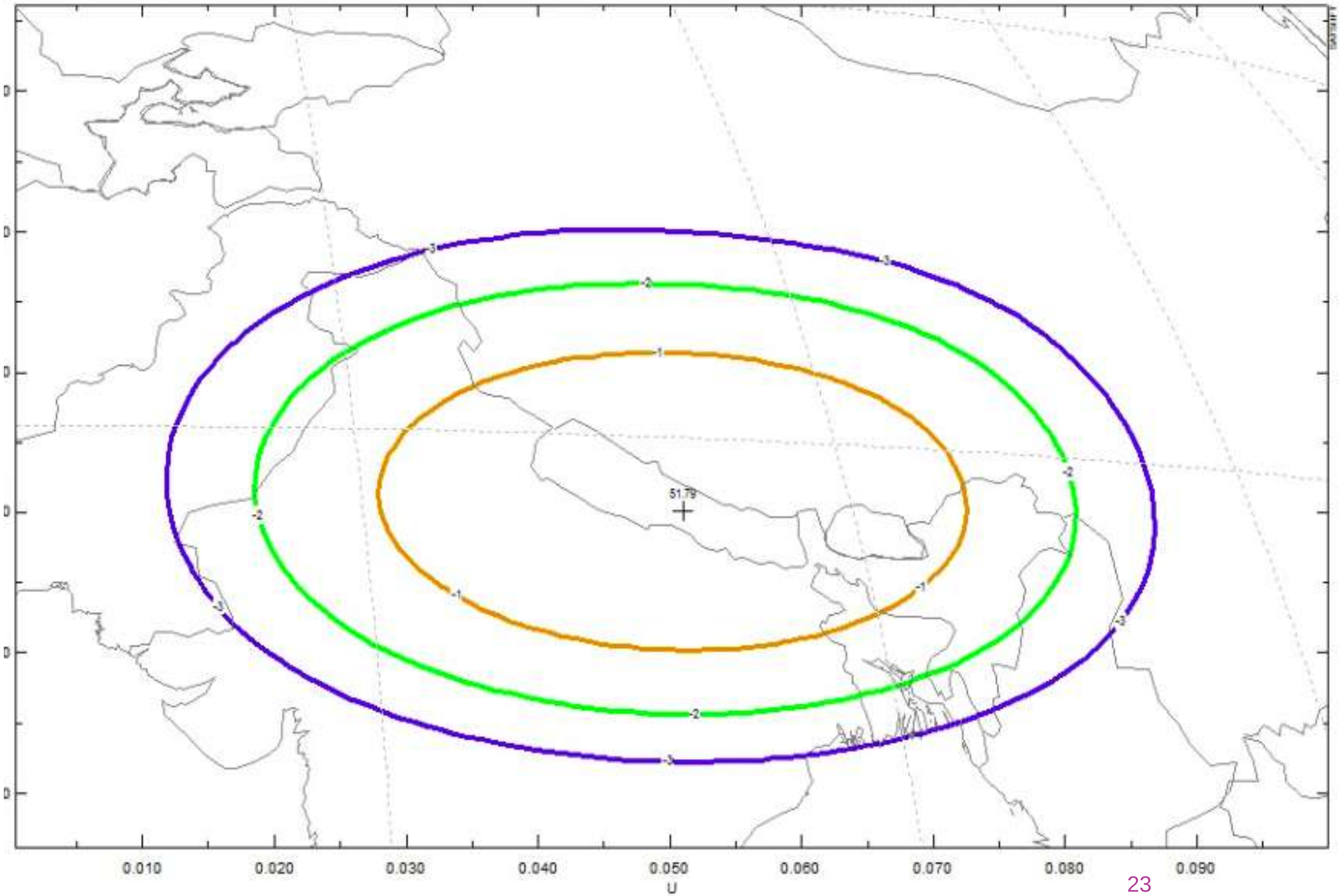
Works Done

- Link-Budget Attempted for two sites – Lalitpur and Pokhara of Nepal

General Specifications

- Orbital location .... 65° East
- Frequency band .... Ku, Ka
- Number of available
  Ku-band Transponders .... 8 x 108MHz
- Number of available
  Ka-band Transponders .... 4 x 216MHz
- Service areas
  - Ku-band beams:
    two shaped steerable beams covering Russia and India with optional steering to: Southeast Asia, the Middle East, Central Asia, India, South Africa and Central East Europe
  - Ka-band beam:
    one shaped steerable beam covering the Middle East. Optional steering to: Russia, India, China, Central Asia, Southeast Asia, and South Africa

KA EIRP OVER NEPAL



OUTBOUND LINK DESIGN

Service Name	Satellite Education Network
Coverage	Nepal
Uplink Earth Station	Pokhara
Downlink Earth Station	NCIT
Satellite Name	AMOS-4
Modcod	DVB-S2 4-PSK (1/2)

LINK INPUT PARAMETERS

	Up	Down	Unit
Link Input Parameters			
Site Latitude	28.1453 N	27.6714N	degrees
Site Longitude	84.0838E	85.3387E	degrees
Site Altitude	1.6555	1.6	km
Polarization	Circular	Circular	
Rain-zone or mm/hr	52.5	46.5	
Availability(average year)	99.5	99.5	%
Antenna Aperture	1.8	1.8	meters
Antenna Efficiency	64	64	%
Coupling Loss	0.1	0.1	dB
Antenna Mispointing Loss	0.5	0.5	dB
Other path losses	0.1	0.1	dB
LNB Noise figure (dB)or temperature(K)		1.6	dB
Uplink Station HPA output back-off	0		dB
Uplink power control	6.13		dB
Number of Carriers/HPA	1		

SATELLITE I/P PARAMETERS

Satellite Input Parameters	Value	Unit
Satellite longitude	65E	degrees
Transponder type	TWTA	
G/T Reference	0	dB/K
SFD Reference	-81	dBW/m2
Receive G/T	8.5	dB/K
Attenuator pad (gain step)	0	dB
Effective SFD	-89.50	dBW/m2
Satellite ALC	0	dB
EIRP (saturation)	51	dBW
Transponder bandwidth	216	MHz

MAJOR RESULTS

Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	3.71dB	0dB	0 dB
HPA Power	3.5662 Watt		
Availability	99.5%		
Link Efficiency	0.654 bps/Hz		
Power Equivalent Bandwidth	6.1133 MHz		

- Utilized QPSK ½ but the system can run upto Modcod of QPSK 4/5 , derived from Es/No=>(1+3.71)=4.71 in clear-sky condition.

INBOUND LINK DESIGN

WORST CASE

Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	7.03dB	-21.81dB	-5.49dB
HPA Power	190.8244 Watt		
Availability	99.98%		
Link Efficiency	0.019 bps/Hz		
Power Equivalent Bandwidth	215.9 MHz		

OPTIMIZED RESULT

Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	4.22 dB	0dB	0 dB
HPA Power	3.0307 Watt		
Availability	99.5%		
Link Efficiency	0.468 bps/Hz		
Power Equivalent Bandwidth	8.5549 MHz		

FURTHER OPTIMIZATION (FROM 4-PSK ½ TO 4-PSK 1/3)

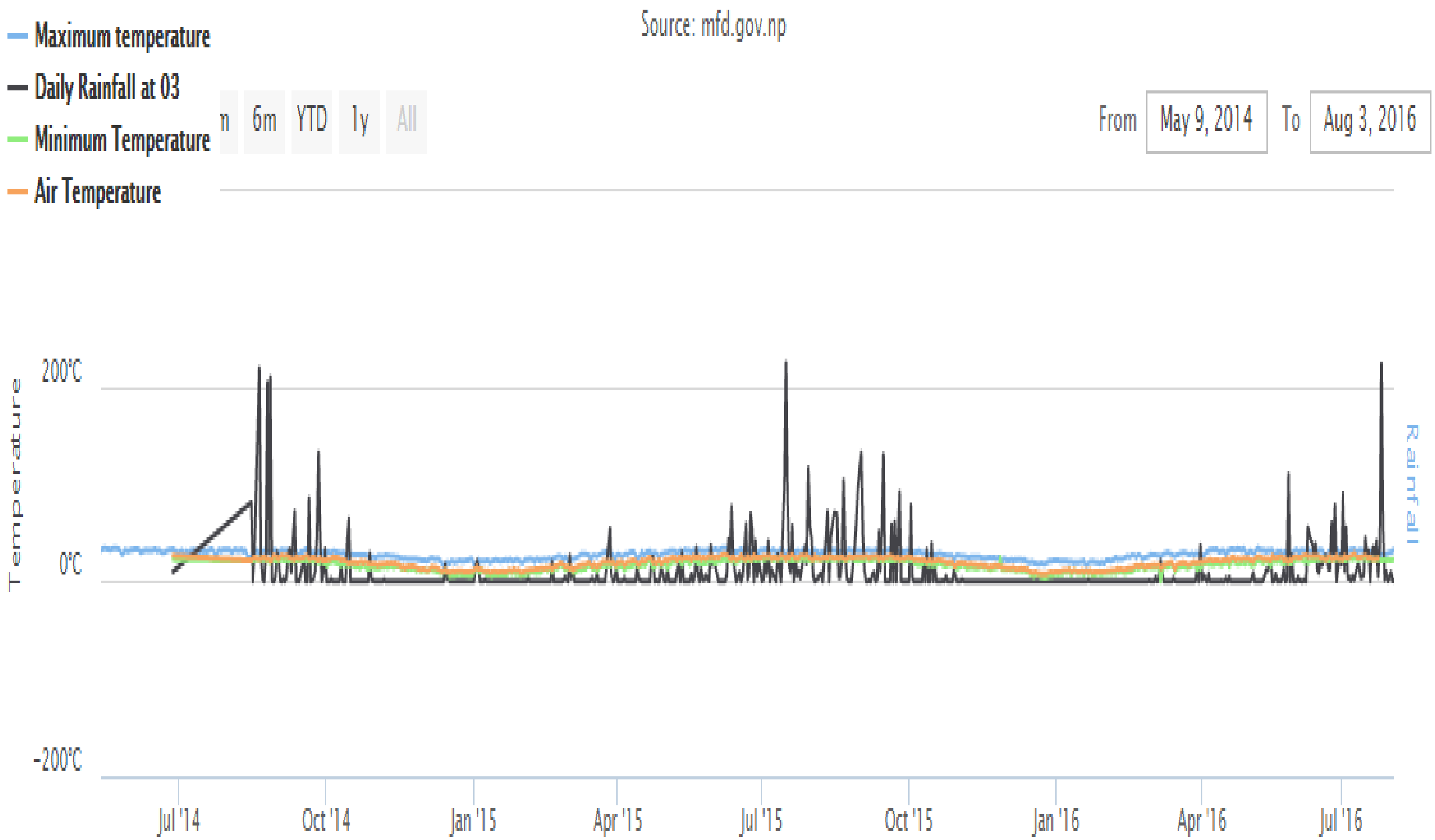
Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	4.37 dB	0.01 dB	0 dB
HPA Power	8.5549 Watt		
Availability	99.5%		
Link Efficiency	0.531 bps/Hz		
Power Equivalent Bandwidth	7.5309 MHz		

- Maximum Modcod that can be used is (-1.24 + 4.22) = 2.98, giving QPSK 3/5 as Maximum Modcod that can be used for clear-sky condition for Inbound.

DUAL-FADE LINK DESIGN(QPSK ¼)

Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	5.33dB	0 dB	0dB
HPA Power	8.1026Watt		
Availability	99.5%		
Link Efficiency	0.407 bps/Hz		
Power Equivalent Bandwidth	9.816 MHz		

LINK DESIGN FOR TRANSPORTABLE SITE



Worst rainfall in the duration of May9,2014 – Aug 3, 2016 in Pokhara

- In case of Pokhara, the highest rainfall is seen in July 16, 2015 as 224 mm for 24 hours.

- The data logger is seen to collect data every three hours.
- Empirical reduction formula. The equation is given as:
- $P_t = P_{24} (t/24)^{1/3}$
- where, Pt is the required rainfall depth (mm) in t-hr , P24 is the daily rainfall (mm)and t is the rainfall duration for which the rainfall intensity is to be calculated.
- Thus for transportable site this worst case condition of 77.65 mm/hr for pocket-rainfall zone Pokhara is considered.

- Random transportable site at (latitude, longitude, altitude) =(29N,84E,5.282km) is selected .
- 99.5 % available Link is balanced with UPC=8.55 and QPSK-3/4 modcod with the following results:

Description	Clear-Sky	Rain -Uplink	Rain-Downlink
Excess Margin	1.44 dB	0 dB	0dB
HPA Power	4.952 Watt		
Availability	99.5%		
Link Efficiency	0.826 bps/Hz		
Power Equivalent Bandwidth	4.843 MHz		

Link Design for Transportable site

CONCLUSION

- Contribution was made utilizing attenuation model to come up with the linkages between attenuation, resources, geographic plus system attributes and quality parameters.

- A link-budget analysis for selected sites with significant attenuation was designed to derive a fairly comfortable margin of approx. 3.71-4.22dB in uplink and downlink scenarios for unexpected sources of losses with 99.5% reliability .

- Reasonable excess Margin of 5.33 dB in case of dual-fade has been derived.

- For Outbound, link is optimized to work in QPSK ½ in rain fade condition and can utilize higher Modcod during clear-sky with HPA Power 3.56 Watts, PEB 6.11 MHz and Spectral Efficiency of 0.654 bps/Hz.

- Likewise, Inbound link is designed to utilize QPSK 1/3 during rain-fade and can go upto higher modulation during clear sky condition.HPA power used is 2.66 Watts , PEB is 7.53MHz and Spectral Efficiency is 0.531bps/Hz.PEB in case of dual-fade link design is higher with the use of 9.8 MHz.

- Hence, a ka band satellite network link design to cover areas of both urbane and remote with acceptable availability was derived for high-speed collaboration and resource sharing.

LIMITATIONS AND FUTURE WORKS

- This work does not deal with Link Optimization by varying the Antenna Size and its simulation.

- Antenna size is kept fixed. Uses ku-band antenna.FMT- Site diversity is not utilized.
- It does not study impact of other atmospheric fading due to cloud and fog which also affects ka-band frequencies.
- Only design for simple three-site network is demonstrated and described for simplicity.

- More intensive simulations like MODCOD vs Antenna size and fog /cloud attenuation simulation can be depicted.

- More advanced network for whole of Nepal can be designed leading to depiction of more work in bandwidth allocation system.

Thank You !