Design and Performance Evaluation of an SDH Based Microwave Digital Radio Core Network

by

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A thesis submitted to the Department of Electrical and Electronic Engineering of

Bangladesh University of Engineering and Technology

in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

2007

APPROVAL CERTIFICATE

The thesis titled " **Design and Performance Evaluation of SDH Based Microwave Digital Radio Core Network** " Submitted by Abu Zafor Mohammad Salahuddin, Roll No: 040506207P, Session: April 2005 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Electrical and Electronic Engineering on February 17, 2007.

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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DEDICATED TO MY PARENTS

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List of Symbols

α	Attenuation constant
β	Propagation constant
ϕ	Propagation phase / Echo phase
ω	Angular frequency
ρ	Electromagnetic power density
η	Antenna efficiency
ε	Slope from Tx to Rx antenna
τ	Reflected relay delay / Echo delay
a	Frequency exponent

b	Echo amplitude / Distance factor
c	Propagation velocity / Speed of light / EM wave
e	Water vapour pressure
n	Refractive index
A	Reflector area / Probability of fade depth
A_{RE}	Effective area around antenna
A_S	Signature area
C	Climatic factor
D	Antenna diameter
F1	Fresnel ellipsoid radius
G	Vertical refractivity gradient
G_T	Tx antenna gain
G_R	Rx antenna gain
K	Geo climatic coefficient / Equivalent earth factor
L	Hop / path length
L eff	Effective hop / path length
P_{DS}	Diversity outage probability due to selective fading
P_{INC}	Incident power
P_{LOST}	Total power lost
P_T	Transmitted power / Non-selective outage probability
P_{TH}	Threshold power
P_S	Selective outage probability
P_R	Received power
P_o	Multipath occurrence factor
Q	Terrain coefficient / Profile factor / Rain Drop Cross Section
R	Earth radius
S	Vertical spacing of Rx antenna
T	Absolute time in Kelvin, degree
T_o	Observation period
T_{out}	Outage time
T_S	Symbol period

U_r	Unavailability due to rain
U_f	Unavailability due to equipment failures
V	Absolute difference of two antenna gain

List of Abbreviations

Adl	Additional Losses
BB	Base Band
BBE	Background Block Error
BER	Bit Error Rate
CL	Clearance
Co-pol.	Co-polarization
CPA	Co-polar Attenuation
DFM	Dispersive Fade Margin
ES	Errored Second
FM	Fade Margin
FSL	Free Space Loss
HRDP	Hypothetical reference digital path
IF	Improvement Factor / Intermediate Frequency
ITU	International Telecommunication Union
ISI	Inter Symbol Interference
NFD	Net Filter Discrimination
PDH	Plesiochronous Digital Hierarchy
SDH	Synchronous Digital Hierarchy
SES	Severely Errored Second
XPD	Cross polarization discrimination
XPIC	Cross Polar Interference Canceller
X-pol.	Cross polarization

Acknowledgements

I am highly pleased to express my sincere and profound gratitude to my supervisor Dr. A.B.M. Siddique Hossain, Professor, Department of Electrical and Electronic Engineering (EEE), Bangladesh University of Engineering and Technology, Dhaka, for providing me the opportunity to conduct research on SDH based microwave digital radio core network. I wish to express my deepest thanks to him for his continuous guidance, suggestions and wholehearted help throughout the course of the work.

I would like to express my special thanks to Md. Attaur Rahman Sarkar, Assistant Professor, Department of Electrical & Electronics Engineering, Bangladesh University of Engineering & Technology, Dhaka for providing materials related to my research work and his generous support. I am also thankful to Dr. Satya Prasad Majumder, Professor & Head, Department of Electrical and Electronic Engineering, Dhaka and all the officials of the departmental library for their help during the course of my work.

I would also like to thank Brigadier General Md. Rafiqul Islam, ndc, psc, Director Signals, Bangladesh Army, Colonel Akhtaruzzaman Siddique, psc, te, Head of Department, Department of Electrical Electronics & Communication Engineering, Military Institute of Science & Technology, Lieutenant Colonel Md. Shahidul Islam, Commanding Officer, 10 Signal Battalion, Dhaka Cantonment, Lieutenant Colonel Kazi Abu Taher, Commanding Officer, 1 Signal Battalion, Bogra Cantonment for their support and continuous encouragement to complete the work.

I would also express my deepest gratitude to my wife Mussarat Jaha, my beloved daughter Adrika Zafor and son Farhan Zafor for their support and encouragement.

Finally, I am grateful to almighty Allah for enabling me to complete the thesis.

ABSTRACT

This research work deals with the development of an SDH based microwave digital radio core network for tri-services organizations of Bangladesh keeping technical, strategic, tactical, operational and administrative issues in consideration. All potential areas of the country have been surveyed and considered for transmission coverage and then radio sites are selected in such a manner that all areas of strategic interest and the ground of tactical importance are covered most effectively.

Important parameters / data of radio equipment and the site survey report are fed to the 'microwave link budget calculation worksheet' in order to obtain path profile report of every radio link needed to form the core network. Basing on the path profile report, the core radio network is designed. The evaluation process of reliability is as ITU-R P.530-7/8 where propagation data and prediction methods required for designing the terrestrial line-of-sight systems is considered.

Basing on the path profile reports and ITU transmission standard, a computer program named 'Microwave Link Evaluation Software' has been developed to assess the performance of the designed links. The developed software performs the analytical comparisons of the performance of the designed network with the ITU published transmission standard to ascertain the correctness of the designed network.

CHAPTER 1
INTRODUCTION

1.1 Telecommunication System

Long distance reliable and cost effective transmission medium is a fundamental need in the telecommunication sector. At present microwave digital radio, communication satellite and optical fiber serve the purposes. Among these, microwave digital radio is the most suitable option for the defense requirement particularly in a country like Bangladesh.

The transmission medium bridges the distance between the source and the destination. It is the component of a telecommunication system that determines many important aspects of the transmitter, the receiver and signal flow. As signal propagates through the medium it gets attenuated due to interaction between the signal and the medium. The signal also gets distorted due to nonlinear characteristics of the medium and other interferences. The transmission medium may be of various types. It includes physical and non-physical media. Physical media includes copper wire, coaxial cable, optical fiber, etc. The non-physical media includes links at various frequencies like high frequency, very high frequency, microwave, etc.

Electronic communication systems became the first dominant modern communication method since the advent of telegraphy in the 1830s. Until the early 1980s, most of the fixed (non-radio) signal transmission was carried by metallic cable (twisted wire pairs and coaxial cable) systems. However, large attenuation and limited bandwidth of coaxial cable limited its capacity upgrade. The bit rate of the most advanced coaxial system which was put into service in 1975 was 274 Mb/s. At around the same time, there was a need of conversion from analogue to digital transmission to improve transmission quality, which requires further increase of transmission bandwidth. Many efforts were made to overcome the drawbacks of coaxial cable during the 1960s and 1970s. After the invention of wireless communication system, signals could be transmitted through the atmosphere using the suitable frequencies as carrier with less attenuation / distortion over a much wider area / distance with increased bandwidth.

1.2 Evolution of Microwave Digital Radio Communication

Microwave radio as a transmission medium has been available for many decades. In the past, microwave analog radio systems had been used as the main transmission bearer in the core network predominately for voice traffic. Gradually, with the increased requirement of bandwidth for both voice and data traffic, optical fiber started replacing microwave radio systems from the core network due to its higher bandwidth and almost error-free transmission characteristics. The fiber optic has relegated microwave radio to second position in the minds of many operators mainly because of the fading of signal on microwave analog radio systems. Anatomically such fading has a limited effect on voice but adversely affects the throughput rates of data services. This questioned the suitability of analog radio for non-error-correcting data standards.

With the advent of microwave digital radio systems in the early 1980s, link performance got dramatically improved but new fading effects called selective fading placed doubts in operator's minds about the suitability of radio for high quality data transmission. Digital radio designers soon realized that radios should not only meet the ITU transmission standards, but that they should also be designed to have comparable performance to fiber optics. As such powerful transversal adaptive equalizers and forward error correction algorithms using convolution code are inducted in the radio system in order to ensure that radio achieves the same inherent bearer transmission quality / standard as fiber (above 10^{-11} up to 10^{-13}) or other alternatives.

1.3 Background of this Research

Though microwave radio system has comparable performance to fiber and other alternatives in terms of reliability and QoS, there is still a perception amongst many that microwave radio is unreliable due to 'fading of signal' and the received signal drops in strength to a point where from the original signal cannot be recovered. Besides, due to rapid development and enormous circulations, optical fiber has become the most obvious and compelling means to the transmission network planners for establishing the backbone network. This shall lead to a technical monopoly of optical fiber in the telecom transmission sector.

Besides, fiber was not always available at the places of interest to connect a new customer or base station to the network or for the last mile access. In many cases, fiber in the access portion of the network is simply not available. Statistically fiber networks connect less than 0.5 % of major commercial buildings in Europe and less than 5 % in the USA. Such statistics shows that the trend to connect fiber to new buildings is slower rather than accelerating, due to the high cost of provisioning fiber. Furthermore some cities like San Francisco have passed bylaws preventing streets being dug up, due to excessive fiber digs after deregulation.

Moreover, fiber is not cost-effective either in the core or in the access part of the network, where the maximum capacity requirements are typically less than STM-4. But it is cost-effective in the core network where extremely high bandwidths are required.

1.4 Research Aims

The aim of this research work is to design and evaluate the performance of an SDH based microwave digital radio core network for tri-services organizations in order to establish that microwave radio system is not a compelling alternative rather in many cases it is the most advantageous option for transmission network up to certain capacity limit.

1.5 Objective of this Research

The objective of this research work is to:

a. Design an SDH based microwave digital radio core network for tri-services organizations (Bangladesh Army, Air Force & Navy) keeping technical, strategic, tactical, operational and administrative issues in consideration and

b. Evaluate the performance of the designed network in terms of reliability and QoS as per ITU-T standards.

1.6 Possible Outcome of this Research

- This thesis shall bring forth following tangible results:
  - a. If designed and engineered properly and precisely microwave radio systems can overcome the potentially detrimental propagation effects.
  - b. Microwave radio system meets international carrier transmission standards for both voice and data services.
  - c. Microwave radio system is a cost effective and practical option for transmission solutions in all parts of a fixed or mobile network.
- This thesis shall also serve as an implementation tool for future transmission infrastructure setup for backbone network.
- Tri-services organizations of Ministry of Defense can implement this core radio network plan for their own use which will be redundant for other operators during peace time need.

1.7 Outline of the Thesis

This thesis paper comprises of seven chapters. The contents of the respective chapters are outlined below:

Chapter 1 is the introductory column of the entire study covering evolution of microwave digital radio communication system, background, aim, objective and possible outcome of the research along with the thesis layout.

Chapter 2 describes fundamentals of radio propagation physics, basic concepts of radio link engineering and other related issues in order to meet the design and performance requirements of microwave digital radio networking system.

Chapter 3 covers the ITU transmission performance target, use of RF band and system design requirements to meet the design and performance requirements of microwave digital radio networking system.

Chapter 4 is the backbone of the study. This chapter describes the link design considerations; transmission capacity requirements; site selections for radio stations; formation of possible backbone network, designing links by path calculation software. The main discussion in this chapter revolves around the analytical formulations of the proposed network architecture.

Chapter 5 describes the analytical comparisons of performance of the proposed network with the ITU published transmission standard to ascertain the correctness of the designed network.

Chapter 6 describes the reasons to select SDH technology for transmission network designing as well as its compatibility and migration possibility to next generation network (NGN).

Chapter 7 contains the conclusions of the work with few suggestions / recommendations for future works.

END OF CHAPTER

CHAPTER 2

PROPAGATION ISSUES IN DIGITAL RADIO LINK ENGINEERING

2.1 Introduction

This chapter describes fundamentals of radio propagation physics, basic concepts of radio link engineering, interference and other related issues in order to meet the design and performance requirements of microwave digital radio networking system.

2.1.1 Related Glossary

Tx Power: RF power at radio transmitter output (usually manufacturer data do not include loss in the RF branching system).

Tx Capacity: Amount of information delivered at the Tx input and available at the Rx output (usually expressed in bit/second or telephone chs or TV chs etc).

Path Bit Rate: Bit Rate (bit/second) actually transmitted on the radio path (it is usually higher than the Tx Capacity, due to bits added by the Tx radio equipment for channel coding, service channels, framing, etc.)

Tx Frequency: The Carrier Frequency in the Emitted Signal.

Emitted Spectrum: The distribution of emitted RF energy at frequencies around the Tx Carrier Frequency. It depends on the (Path) Bit Rate, Modulation technique and Tx Filtering (Tx Spectral Shaping).

Tx Spectral Shaping: Overall effect of Tx Filters in limiting emitted spectrum.

Rx Power (nominal): The RF power at the Radio Receiver Input in normal propagation conditions.

Rx Power (actual): RF power at radio receiver input at a given time including propagation losses present at that time.

Rx Threshold: The minimum RF power at the Rx input, required for the Receiver to operate above a threshold of acceptable quality.

Reception Quality: Result of comparison between original information delivered at Tx input and that available at Rx output; it can be expressed by BER, or by other (more complex) parameters related to bit blocks.

Rx Selectivity: Overall effect of the receiver filters in discriminating the desired signal from signals received on adjacent radio channels. It is expressed by an overall transfer function, including the contribution of RF, IF, and BB filters.

Net Filter Discrimination (NFD): Attenuation of interfering signal level at Rx decision circuit, as a result of interfering signal Tx spectral shaping and of Rx selectivity at interfered receiver.

Isotropic Antenna: An ideal source of EM radiation that radiates uniformly in all directions.

Omnidirectional Antenna: A real antenna that approximates an Isotropic antenna; in most cases radiation is (almost) uniform at all azimuth angles but within a limited range of elevation angles.

Directive Antenna: A real antenna that concentrates most of the emitted radiation within a small angle in a given direction.

Reflector Antenna: A directive antenna using one or more reflecting surfaces to concentrate the emitted radiation in the desired direction.

Parabolic Antenna: A reflector antenna using a parabolic surface; the feeder position is in the parabola focus.

Horn Antenna: A reflector antenna using a sector of a parabolic surface.

Cassegrain Antenna: A double reflector antenna. The primary reflector is a parabolic surface and the secondary reflector is a hyperbolic surface.

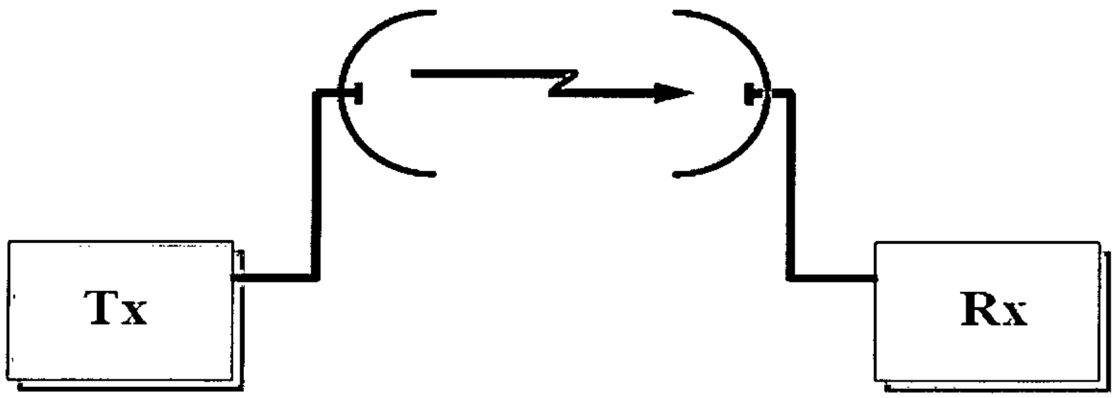
Directivity Diagram: A plot of the antenna gain (usually relative to the maximum gain) as a function of the azimuth or elevation angle.

Far Field Region: Region sufficiently distant from the antenna, where EM field can be represented as a plane wave and antenna diagram is stabilized. Closer to antenna, Near Field Region and Fresnel (transition) Region are defined. Boundary between Fresnel and Far Field Region is approximately at distance:

$$dFF = 2\,D2 / \lambda \quad (D = \text{antenna diameter}) \qquad (2.1)$$

Launch and Arrival Angles: Angle of the Radio Ray at the Tx or Rx antenna, with respect to the Horizon; it varies with atmospheric conditions (k-factor).

2.1.2 Point-to-Point Radio Link



The above diagram shows the basic elements in any point-to-point radio link. These elements are transmitter, antenna, radio hop and receiver. Several important factors / parameters of these elements define the grade of the radio link. Those are for frequency, Tx power and capacity (bit/s, tel. chs) for transmitter; frequency range and gain for antenna; hop length for radio hop; frequency and Rx threshold (related to Rx signal quality) for receiver.

2.1.2.1 Derivation of Basic Radio Link Equation

Let us assume that a radio signal is transmitted using an isotropic antenna, with power P_T. At the distance L from the antenna, the power density ρ is:

$$\rho = P_T / 4\pi L^2 \qquad (2.2)$$

If a directive antenna (gain G_T) is used and assuming that the distance L is sufficiently large, in order that far field conditions are satisfied, then the power density in the antenna pointing direction is:

$$\rho = P_T G_T / 4\pi L^2 \qquad (2.3)$$

At the distance L, a receiving antenna with an effective area A_{RE} is used then the received power is:

$$P_R = \rho A_{RE} = P_T G_T A_{RE} / 4\pi L^2 \qquad (2.4)$$

The effective area is related to antenna gain e.g. $A_{RE} = G_R \lambda^2 / 4\pi$ (λ = wavelength) then the received power can be finally expressed as:

$$P_R = P_T G_T G_R \lambda^2 / [4\pi L]^2 = P_T G_T G_R [C / 4\pi FL]^2 \qquad (2.5)$$

where C is the propagation velocity and F is the signal frequency. By transforming into logarithmic units, we get:

$P_R[dBm]=P_T[dBm]+G_T[dB]+G_R[dB]-92.44-20Log(F[GHz])-20Log(L[km])$ ...... (2.6)

This is the usual radio link equation. If frequency and distance are not expressed, respectively, in GHz and km, then the numerical constant 92.4 must be modified.

Comments: Two equivalent forms of radio link eqn have been derived above:

$$P_R = P_T\, G_T\, \eta\, A_R / 4\pi L^2 \quad (2.7)$$

$$P_R = P_T\, G_T\, G_R\, [C / 4\pi FL]^2 \quad (2.8)$$

The antenna parameters used in (2.7) are Tx gain G_T and Rx antenna area A_R. Rx power is proportional to G_T, A_R and P_T; it is inversely proportional to the distance squared. This probably sounds quite clear from physical point of view. On the other hand, formula (2.8) looks attractive for its symmetric form, since both Tx and Rx antenna gains appear. However, we must remember that, for a given antenna area, gain increases with frequency (see also antenna gain definition). That's why the frequency term appears in (2.8).

2.1.2.2 Definition of Logarithmic Units

Logarithmic units are widely used in radio link engineering computations. The link budget is put in a very convenient form by using logarithmic units. Gains and losses are added with positive or negative sign, as in financial budgets. The ratio R between the power P and a reference power P_{REF} (both in the same unit, like W or mW) is expressed in decibels as R (dB) = 10 Log10 (P / P_{REF}). If R>0 then P > P_{REF} (gain) otherwise if R<0 then P < P_{REF} (loss). Decibels are used to express ratios only. Absolute power levels can never be expressed in dB. Sometimes reference power level P_{REF} is implicit in some way. Absolute power levels can be expressed in dBm, by assuming P_{REF} = 1 mW, P (dBm) = 10 Log10 (P[mW] / 1mW). Similarly, with P_{REF} = 1 W, power P in dBW is P (dBW) = 10 Log10 (P[W] / 1W). Examples of power levels expressed in different units:

Power in mW	**Power in dBm**	**Power in dBW**
0.001	-30	-60
0.1	-10	-40

1.0	0	-30
2.0	+03	-27
5.0	+07	-23
10.0	+10	-20
40.0	+16	-14
100.0	+20	-10
200.0	+23	-07
1000.0	+30	0
5000.0	+37	+07
10000.0	+40	+10

2.1.2.3 Basic Radio Link Equation (Free Space)

The basic parameters in a point-to-point radio link are put together in the radio link equation. The radio link equation computes the Rx power in the absence of any propagation anomaly (free space propagation):

$$P_R = P_T + G_T + G_R - 92.4 - 20 \text{ Log } (F) - 20 \text{ Log } (L) \quad \ldots\ldots\ldots\ldots\ldots \quad (2.9)$$

Where P_T = Transmitted power (dBm) ; P_R = Received power (dBm) (normal propagation) ; G_T = Tx antenna gain (dB) ; G_R = Rx antenna gain (dB) ; F = Frequency (GHz) and L = Hop length (km).

Note: The constant 92.4 is correct only if the frequency is expressed in GHz and the hop length in km. If other units are used, the constant 92.4 must be modified accordingly (e.g. with hop length in miles, the constant is 96.6).

2.1.2.4 Loss vs. Distance in Radio (and Cable) Links

In the radio link equation, the factor $1/L^2$ (or -20 Log (L) in logarithmic units) shows how the received signal power is reduced as the distance L from Tx to Rx increases. We refer to the simple isotropic antenna example. The antenna is at the centre of a sphere (with radius L), radiating a total power P. In every point on the sphere surface, the EM power density (ρ) is $\rho = P / 4\pi L^2$.

The Loss vs. Distance mechanism is directly related to the EM power density at the Rx antenna, which is proportional to $1/L^2$. This corresponds to a 6 dB increase in power loss every time the hop length is doubled. It must be recalled that the radio link equation is valid for free space propagation. Therefore, no interaction between the electromagnetic (EM) radiation and the propagation medium is responsible for power loss. For the above reason, the term free space loss could be slightly misleading. A completely different mechanism is responsible of power loss at the receiver when the EM energy interacts with the propagation medium and some phenomena of energy transfer or transformations produce the attenuation in the received signal.

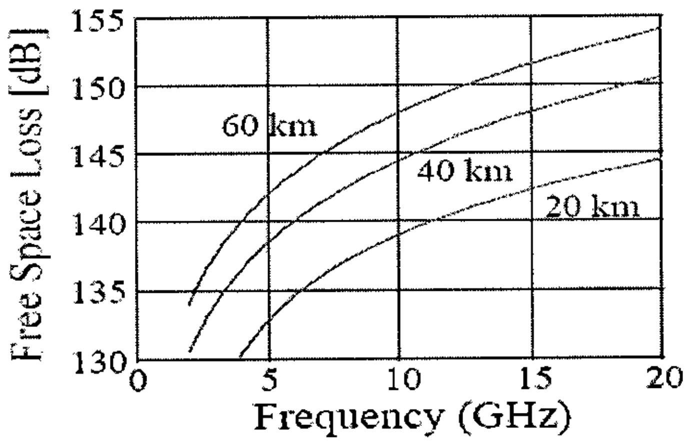
This happens, for example, in coaxial cable transmission, where signal loss is mainly due to dissipative phenomena (interaction of EM energy with conductive and dielectric material in the cable). Depending on signal frequency and cable characteristics, some fraction of signal power is lost every kilometer traveled through the cable. So, the loss is usually expressed in dB/km. Also in radio communications through the atmosphere, dissipative phenomena can be observed. Absorption in the atmosphere is caused by water vapour, oxygen molecules or by water in raindrops. Also for these phenomena, the power loss is usually expressed in dB/km. However, in most cases (dry atmosphere, frequencies below 20 GHz), the interaction of the EM radiation with atmosphere components is almost negligible.

2.1.2.5 Free Space Loss (FSL)

The radio link equation can be also written as $P_R = P_T + G_T + G_R - FSL$
FSL is the free space loss and can be expressed as:

$$FSL\ (dB) = 92.4 + 20\ Log\ (F) + 20\ Log\ (L) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2.10)$$

The free space loss is often referred as 'Loss between Isotropic Antennas'. In fact, for isotropic antennas (gain = 0 dB). Therefore the radio link equation becomes: $P_R = P_T - FSL$. Point to note that FSL increases 6 dB if the hop length is doubled or the frequency is doubled.



Examples:

1.9 GHz 60 km FSL = 133 dB
3.8 GHz 60 km FSL = 139 dB
7.6 GHz 30 km FSL = 139 dB
15.2 GHz 30 km FSL = 145 dB

2.1.2.6 Mathematical Explanation of Antenna Gain

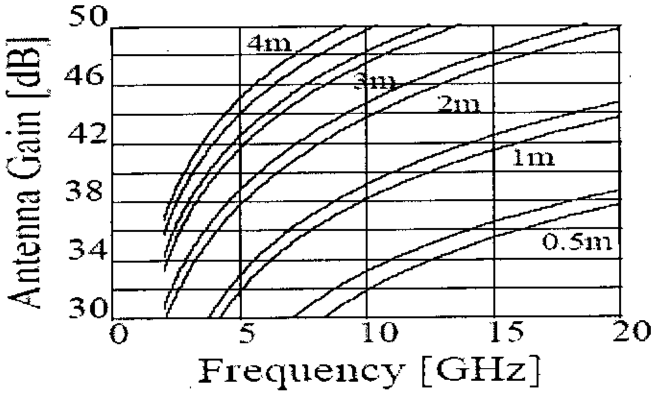
Let us imagine an isotropic antenna at the centre of a sphere (with radius L), radiating a total power P. In every point on the sphere surface, a uniform EM power density (ρ) could be measured as (ρ)ISO = P / $4\pi L^2$. Now, we substitute the isotropic antenna with a directive antenna and we measure the EM power density on the sphere surface, at the intersection with the antenna axis (we maintain the same total emitted power P). The result is (ρ)DIR . The antenna gain on the axis is defined as g = (p) DIR / (p) ISO. In logarithmic units, G (dB) = 10 Log (g) = 10 Log [(p) DIR / (p) ISO]. Antenna gain depends on the physical dimensions of the antenna, normalized to the signal wavelength (λ). For reflector antennas we have:

$$G\ (dB) = 10\ Log\ (4\ \pi\ \eta\ A / \lambda^2) = 10\ Log\ (4\ \pi\ A_E / \lambda^2) \quad \text{......... (2.11)}$$

where A is the reflector area, η is the antenna efficiency (generally in the range 0.55 - 0.65) and $A_E = \eta A$ is called antenna effective area.

2.1.2.7 Relation between Antenna Directivity and Antenna Gain

Antenna directivity mainly depends on the antenna diameter to wavelength ratio (D/λ ratio). The maximum gain is proportional to $(D/\lambda)^2$. For parabolic antenna, G = $\eta\ (\pi D/\lambda)^2$ where η = Antenna Efficiency = 0.55 - 0.65. In dB units, G = 20 Log (D) + 20 Log (F) + 18.2 + 0.5 (depending on η) .... (2.12)



Antenna gain is 6 dB higher if:

a. Antenna diameter is doubled, for a given frequency.

b. Frequency is doubled, for a given diameter.

2.1.2.8 Approximate Link Budget

By using logarithmic units (dB, dBm), the radio link equation is put in a very convenient form. Gains and losses are added with positive or negative sign. The radio link equation is presented in the form of a simple link budget. Example of a 50 km 7GHz link:

	Power	Gains	Losses
Transmitter Power P_T	+30.0 dBm		
Tx Antenna Gain (3 m diameter)		42.5 dB	
Free Space Loss			143.3 dB
Rx Antenna Gain (3 m diameter)		42.5 dB	
Received Power P_R	- 28.3 dBm		

A more detailed link budget may include additional losses caused by Tx / Rx components (feeders, branching, etc.) and by propagation impairments.

2.1.3 Terrestrial Radio Relay Links

2.1.3.1 Propagation in Lower Atmosphere at Frequencies 1 to 40 GHz

In comparison with free space propagation, a terrestrial radio-relay link is affected by the presence of the atmosphere and ground. They produce a number of phenomena which may have a severe impact on radio wave propagation. Propagation anomalies mainly depend on frequency, hop length, ground characteristics, meteorological and climatic conditions. Propagation anomalies produce additional attenuation, which reduces the Rx power. In most cases such phenomena are of short duration. In particular cases the Rx signal is also distorted in some measure.

2.1.3.2 Effects of Lower Atmosphere on Propagation

Effects of the atmosphere are atmospheric absorption (without rain); refraction through the atmosphere e.g. ray curvature and refraction through atmosphere e.g. multipath propagation. Effects of rain are raindrop absorption; raindrop scattering and RF signal depolarization. Effects of ground are diffraction through obstacles and reflections.

2.1.3.3 Radio Link Engineering - Fade Margin

In a well designed radio-relay link, Rx power should be close to the free space level for most of the time. The radio link is usually designed in such a way that the received power (P_R) at normal propagation conditions is much greater than the receiver threshold P_{TH}. Therefore fade margin (FM) is defined as:

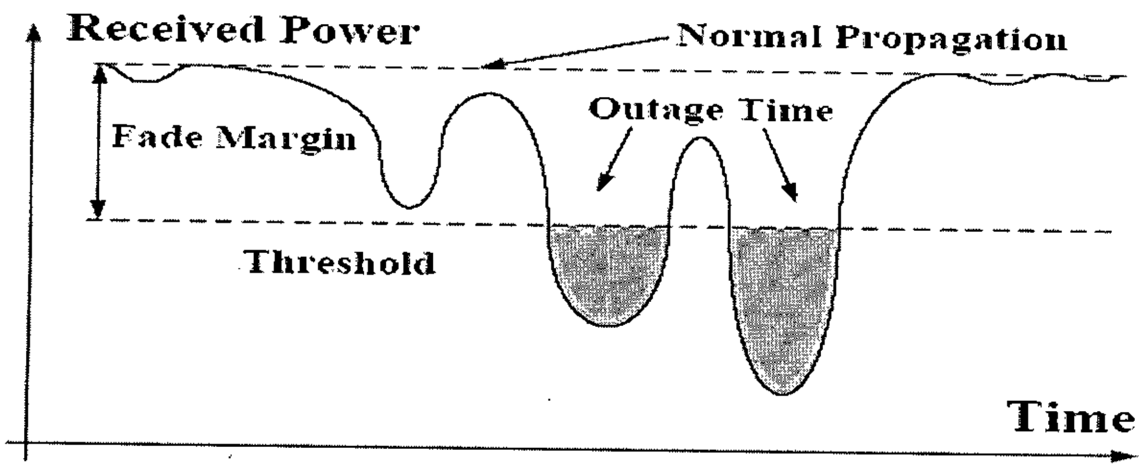
$$FM\ (dB) = P_R\ (dBm) - P_{TH}\ (dBm) \quad \ldots\ldots \quad (2.13)$$

FM is required to compensate for the reduction in Rx power caused by propagation anomalies. It also guarantees that the link will operate with acceptable quality, even if propagation anomalies cause additional losses (AdL), as long as the additional loss is lower than FM i.e. AdL < FM

2.1.3.4 Outage Prediction

Generally speaking, an outage is observed when the Rx power is below the Rx threshold ($P_R < P_{TH}$). So, the outage probability is:

$$\text{Prob}\{\text{Outage}\} = \text{Prob}\{P_R < P_{TH}\} = \text{Prob}\{AdL > FM\} \quad \ldots\ldots \quad (2.14)$$



2.1.3.5 Complete Link Budget

A more complete Link Budget example (7GHz, 50 km link) is:

	Power	Gains	Losses
Transmitter Power (P_T)	30 dBm		
Tx Feeder & Branching Loss			1.4 dB
Tx Antenna Gain (3 m diameter)		42.5 dB	
Free Space Loss			143.3 dB
Additional Propagation Losses			3.0 dB
Rx Antenna Gain (3 m diameter)		42.5 dB	
Rx Feeder & Branching Loss			1.4 dB
--			
Net Path Loss			64 dB
Received Power (P_R)	- 34 dBm		

Assuming Rx Threshold P_{TH} = -77 dBm, FM = $P_R - P_{TH}$ = 43 dB

2.2 Atmospheric Propagation and Refraction

Radio waves propagate along a straight line only if EM parameters in the propagation medium are homogeneous. In the atmosphere, refractive index modifies as the distance from ground increases (vertical refractivity gradient). This is due to the vertical gradient of basic atmosphere parameters, such as temperature, humidity, and pressure. Several anomalies in EM propagation are produced by variations in the refractive index like ray curvature, multipath propagation and duct propagation.

2.2.1 Atmosphere Structure and Refraction Gradient

Refractive index is the ratio of velocity of light in vacuum to the velocity in a different medium. Since velocity of light in the atmosphere is very close to that in vacuum, refractive index in the atmosphere is greater than, but very close to 1. However, also small variations in the atmosphere refractive index have significant effects on the propagation of EM waves. For this reason, instead of using refractive index n (close to 1), it is convenient to define refractivity N as $N = (n - 1)\,10^6$ that is the number of parts per million that refractive index exceeds unity. Refractivity is a dimensionless parameter and measured in N-units. The atmosphere refractivity is a function of temperature, pressure and humidity and it is not constant with height. ITU-R Rec. 453 gives the formula:

$$N = (77.6 / T)\,(P + 4810\, e / T) \qquad (2.15)$$

Where T = absolute temperature (Kelvin deg);P = atmospheric pressure (hPa, numerically equal to millibar); e = water vapour pressure (hPa).

The average value of N at sea level is about No = 315. ITU-R gives world maps with mean values of no in February and August. Vertical refractivity gradient (G) (measured in N-units per km, N/km) is defined as $G = (N1 - N2) / (H1 - H2)$, where N1 and N2 are the refractivity values at elevations H1 and H2, respectively. In a standard atmosphere model, vertical refractivity gradient is assumed as constant in the first kilometer of the atmosphere i.e. G = - 40 N/km. This corresponds to the standard propagation conditions.

Deviation from the standard atmosphere condition leads to anomalous propagation. Such anomalies are usually associated with particular meteorological conditions, like temperature inversion, very high evaporation and humidity, passage of cold air over warm surfaces or vice versa. In this condition, vertical refractivity gradient is no longer constant. A number of different profiles have been observed and measured. It is worth noting that, at greater altitude, refractive index is, in any case, closer and closer to 1; so refractivity (N) goes to zero, according to an exponential function.

2.2.2 Effects of Vertical Refractivity Gradient

In any point in the space, an EM wave propagates in the direction normal to the wave-front (iso-phase plane) in that point. In a homogeneous medium, isophase planes are parallel to each other and the propagation direction is a straight line normal to them.

Atmosphere is not a homogeneous medium. Refractivity varies with height and vertical refractivity gradient gives a measure of this variation. Different refractivity at different heights means different propagation velocity. The wave-front moves faster or slower depending on the height, producing a rotation of wave front itself. Thus also the propagation direction (normal to wave-front) rotates. The ray curvature 1/r is a function of the vertical refractivity gradient G. Mathematically $1/r = -G\ 10^{-6}$. In the equivalent earth representation, the ray path is made straight, by modifying the earth radius R (6370 km) to kR (k = equivalent earth factor). This condition means $1/kR = 1/R - 1/r$ and from there:

$$k = 1 / (1 - R/r) = 1 / (1 + R\,G\,10^{-6}) = 157 / (157 + G) \quad \text{(2.15)}$$

For standard atmosphere (G = -40 N units/km), this gives k = 4/3 (= 1.33).

2.2.3 Anomalous Propagation Conditions

2.2.3.1 Constant G Profiles

Deviation from the standard atmosphere (k = 4/3), can result in sub-refractive and super-refractive propagation. Sub-refractive propagation (k < 4/3, G > -40 N-units/km) is usually associated to atmosphere density increasing with height (warm air over cool air or moist surface). The ray curvature is reduced or even is bent upward ($k < 1$, $G > 0$); the ray path is closer to the ground (maximum obstruction probability when k is minimum). On the other hand super-refractive propagation ($k > 4/3$, $G < - 40$ N-units/km) is observed when temperature inversion happens or other phenomena makes atmosphere density decreasing with height. (cool dry air over a warm body of water). The equivalent earth reduces its curvature; for $k \rightarrow \infty$ the ray is parallel to the earth and propagation may extend its range (unexpected interference may appear). In extreme super-refraction conditions ($G < -157$ N-units/km, negative k) the ray is bent toward ground and no signal arrives at the Rx antenna (black-out).

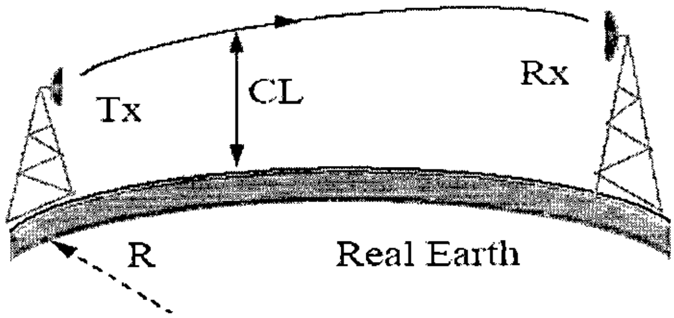
2.2.3.2 Variable-G Profiles

With better approximation, the refractivity gradient can be assumed as constant only in limited height ranges (layered atmosphere). Under this model, the ray curvature changes when passing from one atmosphere layer ($G = G1$) to the higher (or lower) one ($G = G2$). Even if, in the real case, the transition from one layer to another is smooth in some way, a layered atmosphere model is useful in explaining multipath propagation and duct formation.

In multipath propagation, the different ray curvature in atmospheric layers may produce a number of separate propagation paths from the transmitter to the receiver. On the other hand, while propagating through atmospheric duct, the atmospheric layers are such that the rays at the duct lower boundary tend to be bent upward, while rays close to the upper boundary tend to be bent downward. The result is that propagation is confined within a limited height ranges, with attenuation much lower than in well mixed atmosphere. If the Rx antenna is within the duct, a stronger signal will be received. If the Rx antenna is out of the duct, rather long signal fadings are observed.

2.2.4 Ray Curvature in Atmospheric Propagation

Up to about 1 km height, refractive index usually decreases with height, at a constant rate. This means that refractivity gradient (rate of variation) is constant. As a result, the path (radio ray) from the Tx to the Rx antenna is bent in some measure. The ray curvature is proportional to the refractivity gradient. Thus it depends on the atmosphere parameters at any given time.

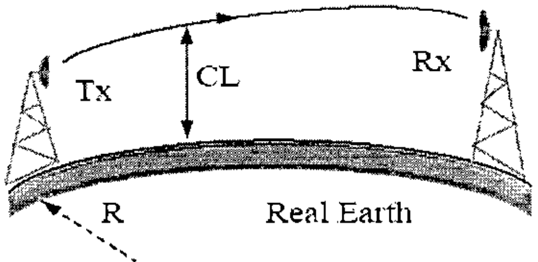


To check the visibility between Tx and Rx antennas, joint effects of radio ray curvature, earth curvature and terrain profile have to be considered.

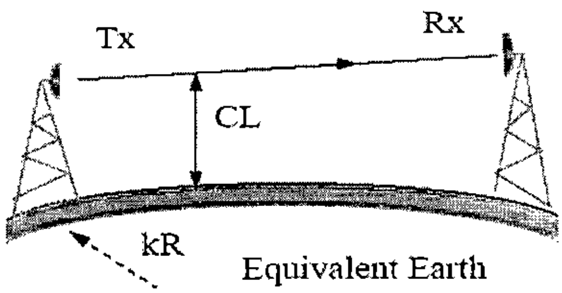
The clearance CL is defined as the distance of the radio ray to the ground. A negative clearance means that a ground obstruction is higher than the ray.

2.2.4.1 Equivalent Earth Curvature

An 'equivalent earth curvature' can be defined by altering the 'real earth curvature' in order that the radio ray path is straight.



Real earth and straight ray diagrams are equivalent. Vertical distance CL from the radio ray to the earth surface is the same in any point of the two diagrams.



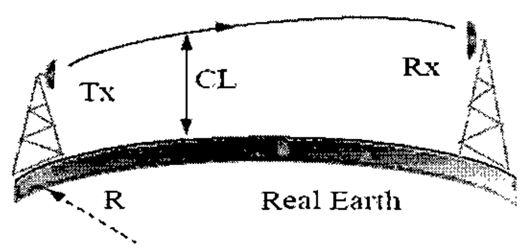
In the equivalent earth representation earth radius (R) is multiplied by a factor k. The value of k-factor depends on the curvature of the radio ray.

2.2.4.2 What Does K-Factor Mean?

K-factor is a measure of the ray curvature effect, produced by the variation in the atmosphere refraction index with height. So, the k-factor is related to the vertical refractivity gradient (G). The k-factor indicates the atmosphere state at a given time and its effect to the radio ray curvature. In a well-mixed atmosphere (standard atmosphere), the refractivity decreases with height at a constant rate. This corresponds to the so-called standard condition, with a stable k-factor, equal to about 4/3. Other k-factor conditions are sub-refractive and super-refractive atmosphere. In sub-refractive atmosphere, $k < 4/3$ and the ray path is closer to the earth. The lowest k value corresponds to the highest probability that the radio ray be obstructed by the ground. But in super-refractive atmosphere $k > 4/3$ and ray path is more distant from the earth. The range of the radio transmission can be significantly expanded. Unexpected interference can be observed.

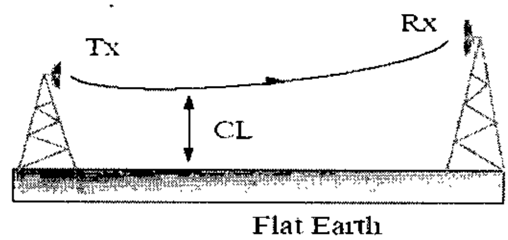
2.2.4.3 Flat Earth Representation

Flat earth representation is an alternative way to plot the radio ray path from the Tx to the Rx antenna. The earth profile is forced to be flat and the radio ray curvature is altered accordingly.



Real earth and flat earth diagrams are equivalent. Vertical distance CL from radio ray to earth surface is the same in any point of the two diagrams.

Radio rays representing different k values can be shown on the same flat earth diagram. This is the more usual representation, particularly in computer aided link design.



2.2.5 Visibility Analysis

Point-to-point radio relay links are usually designed under the requirement of visibility between the two hop terminals. Two factors to be considered in defining visibility criteria in a radio path:

a. Variability in atmospheric conditions producing different ray curvatures. Tool to be used is the statistical distributions of k-factor and the objective is to find the typical and minimum k-factors appropriate for that path.

b. Effects of partial obstructions along the radio path. Tool to be used is the Fresnel ellipsoids and diffraction analysis. The objective is to identify the clearance rules to be applied (minimum distance between radio ray and ground).

2.2.5.1 Diffraction Analysis

Diffraction effects can be observed when wave propagation is altered by an obstacle which has dimensions comparable to the wavelength in the plane normal to the propagation direction. Usually this means that the obstacle is close to the Fresnel ellipsoid (possibly with partial or total obstruction). Theoretical computation of diffraction loss is rather complex. Usually reference is made to two obstacle models i.e. smooth spherical earth and knife-edge obstruction. They represent extreme and opposite conditions and the most practical cases can be assumed as intermediate between these two models. The ITU-R Recs. 368 and 526 include the analysis of the two models. In Rec. 526, Knife-edge model is generalized to rounded obstacles and the case of multiple obstructions is also dealt with. An approximation for the knife-edge case is given by:

$$\text{Diffraction Loss (dB)} = 6.9 + 20 \text{ Log } [\sqrt{(y^2 + 1)} + y] \quad \text{.......... (2.16)}$$

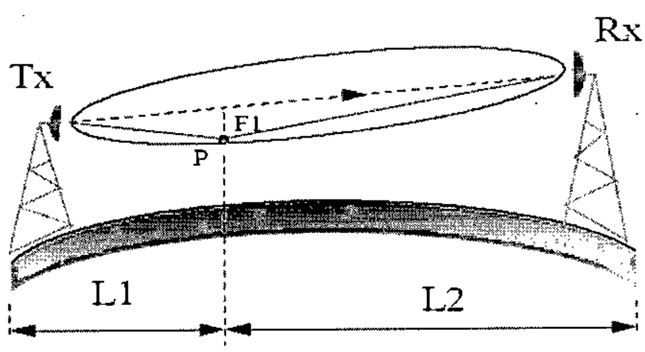
where y = √2 CL/F1 - 0.1 is a function of the clearance CL normalized to the fresnel radius F1, and the approximation is valid for y > - 0.8 (Note: CL is negative when a ground obstruction is higher than the radio ray).

2.2.5.2 Fresnel Ellipsoid and Optical Analogy

The propagation of radio waves is often described in terms of ray trajectories, with implicit reference to geometrical optics. Reflection and refraction phenomena are mainly discussed in this context. However, it is important to remember that the geometrical optics approach is adequate so long as any discontinuities encountered by an EM wave during its propagation are very large compared with the wavelength. Fresnel ellipsoid gives an indication of the space volume involved in the propagation from a source point (Tx) to a sensor (Rx). Ellipsoid radius is proportional to the wavelength square root. In the optical field, the wavelength is so small (about $5\ 10^{-4}$ mm) that the radius of Fresnel ellipsoid is negligible at least as a first approximation. Only with accurate experiments diffraction phenomena can be observed and the role of Fresnel ellipsoid can be appreciated also in the optical field. We are familiar with our optical experience that can be of some help in describing some aspects of propagation mechanisms. But this analogy can be misleading in other case. For example, the concept of visibility is quite different in radio engineering and in our visual experience.

2.2.5.3 Fresnel Ellipsoid with Example

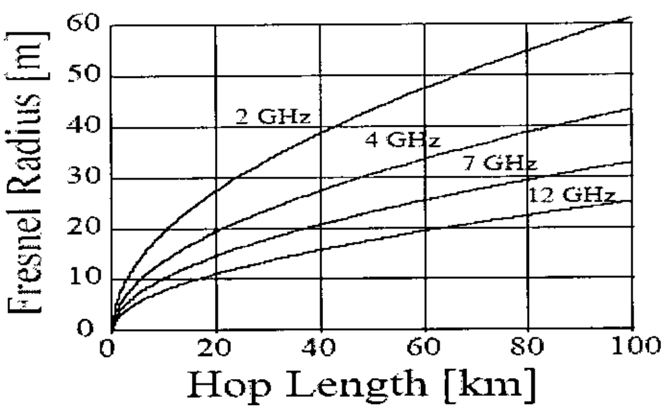
Fresnel ellipsoid gives an estimate of the space volume involved in the propagation phenomena from Tx to Rx. The points on the Fresnel ellipsoid satisfy the relation TxP + PRx = TxRx + λ/2. A radio wave through



the path Tx-P-Rx arrives at the receiver with 180° phase shift with respect to the direct path Tx-Rx. About half of the Rx signal energy travels through Fresnel ellipsoid. So any obstruction within Fresnel ellipsoid has some impact on the Rx power. F1 is Fresnel ellipsoid radius, depending on distance L1 from the hop terminal. The Fresnel ellipsoid radius at a distance L1 (km) from one hop terminal is

$$F1=\sqrt{300L1\ (L-L1)\ /\ (FL)}\ (m) \quad (2.17)$$

Where F = Frequency (GHz), L = Hop length (km) and F1 depends on the signal frequency. In the figure Fresnel ellipsoid radius is at the middle of the path (L1=0.5L).



Other path positions:

R (L1=0.3L) = 0.92 * R (L1=0.5L)

R (L1=0.1L) = 0.6 * R (L1=0.5L)

R (L1=0.01L) = 0.2 * R (L1=0.5L)

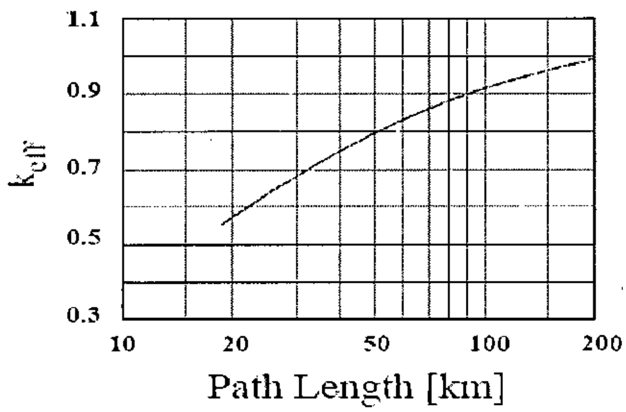
2.2.6 Variability of the k-Factor

The k-factor is related to the atmospheric vertical refractivity gradient G (measured in N-units / km). In standard atmosphere G = - 40 N-units / km and k = 4/3. The G and k-factor are time varying parameters, depending on daily and seasonal cycles and on meteorological conditions. Their range of variation is more or less wide, depending on the climatic region.

In cold and temperate regions the range is rather narrow, while in tropical regions it is very wide. Experimental observations show for example that the probability of k<0.6 in temperate climates is generally well below 1%. In tropical climates the same probability may be in the range 5% - 10%. This means that, in tropical regions, there is the highest probability of observing propagation anomalies due to extreme k-factor values. The ITU-R gives world maps of the time percentage with G < -100 N-units / km (k > 2.75), in different months.

2.2.6.1 Minimum k-Factor

When atmospheric conditions determine the minimum k-factor, then the radio ray is closer to the ground (maximum obstruction probability). In a radio hop an effective k-factor k_{eff} can be defined, taking into account the local k-factor values along the hop. For given climatic conditions, k_{eff} is a function of the hop length (on long hops, k_{eff} is likely close to standard values; extreme atmosphere conditions are probably not present on the whole hop).

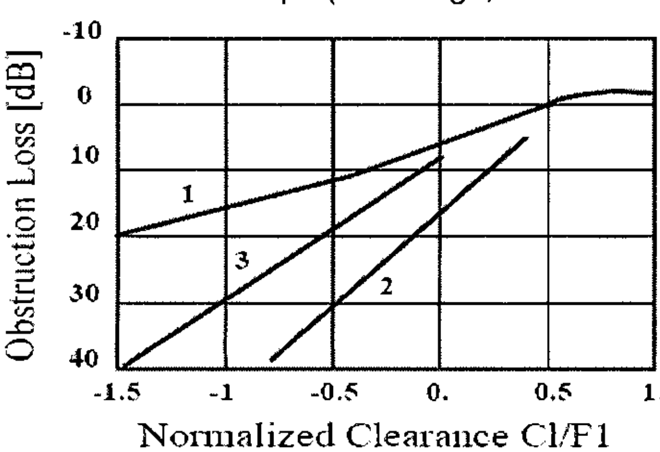


ITU-R gives a curve of minimum k_{eff} values as a function of hop length (temperate climate).

This curve can be used in establishing the worst case condition to check Visibility Criteria.

2.2.7 Obstruction Loss

The clearance (CL) is the vertical distance from the radio ray to the ground. The obstruction loss depends on obstruction height (normalized clearance CL/F1) and obstruction shape (knife-edge, earth curvature etc).



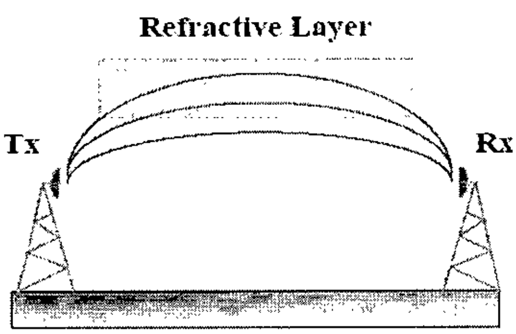
In the figure loss in Rx power caused by obstructions with different shapes is shown i.e. shape-1 knife-edge; shape-2 earth curvature (beyond the horizon link) and shape-3 intermediate case. The normalized clearance (x-axis) is positive for obstacles below the ray, and negative for obstacles above the ray.

2.2.8 Clearance Criteria

In any point of the radio path, the clearance CL is the distance from the radio ray (depending on the k-factor) to the ground. If possible, derive k-factors from local data. For temperate climate, minimum k-factor from ITU-R data should to be considered and in absence of specific data, typically k = 4/3 and minimum k = 2/3. Clearance criteria at any point between Tx and Rx should be CL > 100% F1 with typical k and CL > 60% F1 with minimum k. When a frequency below 2 GHz is used clearance criteria should be CL > 60% F1 with typical k and CL > 30% F1 with minimum k.

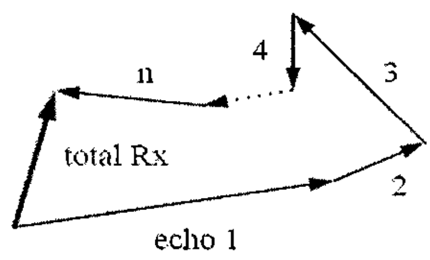
2.3 Refraction through Atmosphere

2.3.1 Multipath Propagation Analogy



When atmospheric stratification is such that the refractivity varies with altitude according to particular profiles, it may happen that the energy from the Tx travels to the Rx over several spatially distinct paths (multipath propagation).

Under multipath propagation conditions, several 'echoes' of the Tx signal arrive at the Rx antenna with random amplitude, delay, and phase shift. The received signal can be represented as the addition of multiple vectors.

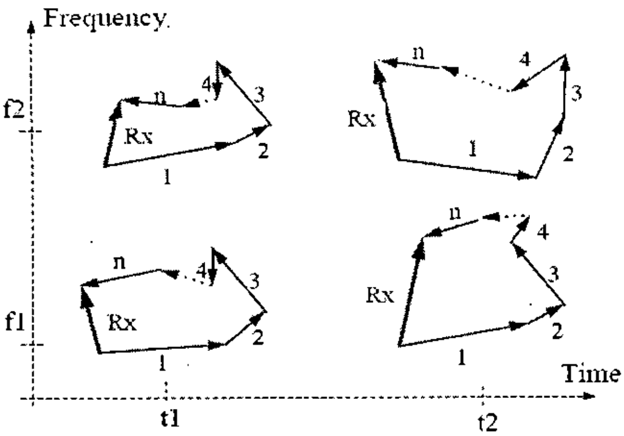


2.3.2 Rx Level vs. Time and Frequency at Multipath Propagation

In a frequency & time plane, the figure shows the addition of multiple vectors with random phases. Each vector represents one Rx signal component, during a multipath event. The Rx signal amplitude changes from time t1 to t2, as well as from frequency f1 to f2. Multipath propagation is a dynamic event, both in the time dimension and in the frequency dimension.

2.3.2.1 Rx Signal vs Time

Phase shifts are varying with time because of movements in atmospheric layers. Since the wavelength is rather small (e.g. 10 cm at 3 GHz), even a small change in the path length produces a significant phase rotation. So the relative phases among multipath components are fast varying, as well as the resultant vector (Rx amplitude).



The speed of change of the multipath channel is expressed in two ways. Firstly, Rx signals power variation in a given time interval. Up to 10 dB in 100 ms (100 dB/s) has been observed, according to several authors. Secondly, fade notch (deepest attenuation) movement through the signal bandwidth. Upto 10 MHz in 100 ms (100 MHz/s) has been observed, according to several authors. These estimates affect the design of multipath countermeasures, like adaptive equalizers, combiners and switches to the protection channel (frequency diversity).

2.3.2.2 Rx Signal vs Frequency

In a modulated signal, let us consider the spectral components at the edge of the signal bandwidth ΔF. Therefore $F1 = F_C - \Delta F/2$ and $F2 = F_C + \Delta F/2$ (F_C = carrier frequency). Moreover, let us simplify the multipath propagation as the composition of a direct and a delayed (echo) signal. The phase shift between the F1 signal component and the delayed echo is $\phi 1 = 2\pi\tau\, F1$ where τ is the echo delay. Similarly, at F2, we have $\phi 2 = 2\pi\tau F2$. The multipath propagation produces an (almost) flat attenuation through the whole signal bandwidth ΔF, if the phase shifts $\phi 1$ and $\phi 2$ are equal (or very close) (same composition of the direct and echo signals at F1 and F2). Therefore, $\Delta\phi = \phi 2 - \phi 1 = 2\pi\tau (F2 - F1) = 2\pi\tau \Delta F \approx 0$ i.e. $2\pi \Delta F << 1 / \tau$.

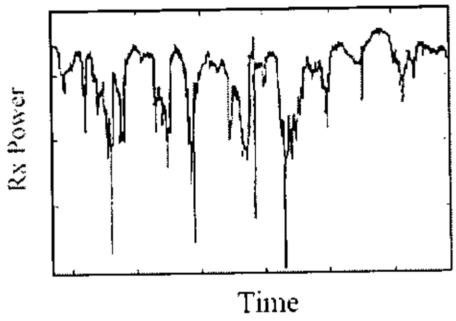
Under this condition, the frequency selective effect of multipath propagation can be neglected; otherwise, for frequencies spaced more than ΔF above, the composition of multipath components, at the same time instant, gives different Rx amplitudes (frequency selective multipath).

2.3.3 Impairments due to Multipath Propagation

Multipath propagation creates mainly three major impairments. Firstly, the received power level is determined by combining a number of signal echoes. Depending on the instantaneous phase shifts of echo components, the Rx signal is subjected to fast amplitude variations. For this reason, multipath propagation is responsible of fast fading phenomena. Secondly, echo phase shift are frequency dependent. The fade depth produced at a given time by combining signal echoes varies with frequency. Multipath fading is 'frequency selective'. The frequency selective fading has a significant impact on wide-band digital signals e.g. amplitude distortions and group delay distortions. This causes 'Intersymbol Interference (ISI)'. Lastly, the cross polarization discrimination (XPD) is reduced during multipath events. This enhances the interference between cross polarized channels.

2.3.4 Multipath Fading Events

Multipath events are observed with daily and seasonal cycles, when atmospheric stratification is more likely to happen. They are more frequent with strong evaporation (high temperature and humidity), absence of wind and flat terrain.

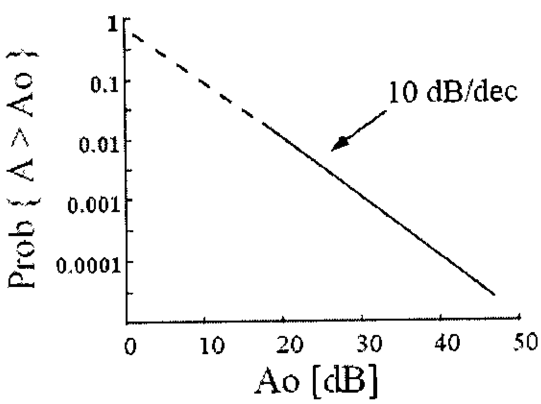


During multipath propagation events, the Rx signal level varies very fast. It may be almost cancelled, for short periods (fraction of a second, or few seconds). A multipath activity period can last some minutes or even one hour or more.

Multipath activity depends on environmental conditions and on radio link parameters. Particularly in tropical climates, long multipath events can be observed.

2.3.4.1 Multipath Fading Statistics

When the Rx signal is produced by a large number of components (vectors with random phases), then Rx power level is variable with Rayleigh statistics. The probability of having a fade depth A (dB) greater than a given depth A_O is found by Rayleigh formula i.e. Prob $\{A > A_O\}$ = $P_O\, 10^{-A_O/10}$, where P_O = multipath occurrence factor which is a measure of multipath activity in a radio hop.



In an operating hop, P_O is estimated by monitoring the Rx Power and by processing the measured data. In a hop under design, P_O is predicted by empirical propagation models.

2.3.4.2 Multipath Occurrence Factor with Example

The multipath occurrence factor P_O depends on frequency; hop length; climatic conditions and terrain. P_O can be predicted using empirical formulas, proposed by ITU-R and by operating companies or research labs. A general formula is:

$$P_O = K\, Q\, F^a\, L^b \quad \text{...(2.18)}$$

Where F = frequency; L = hop length; K = geo-climatic coefficient and Q = terrain coefficient. The frequency exponent (a) is close to unity. This means that the fading activity in a given hop is proportional to the frequency (at 11 GHz is approximately twice than at 5.5 GHz). The distance exponent (b) is in the range 3 - 3.6. This means that the fading activity, for a given frequency, climate and terrain, is increased about ten times if the hop length is doubled. According to the prediction models, for 6 GHz hop, P_O expected in the ranges is as follows:

	30 km	50 km	65 km
Dry climate, mountains	0.01 - 0.05	0.05 - 0.2	0.12 - 0.5
Temperate climate, average terrain	0.05 - 0.12	0.2 - 0.6	0.5 - 1.5
Tropical, humid climate, average terrain	0.15 - 0.4	0.8 - 2.0	1.8 - 4.5
Tropical, humid climate, wet terrain	0.4 - 2.0	2.0 - 10	5.0 - 20

Linear scaling is applicable to other frequencies i.e. for 3 GHz, divide by 2 the P_O values computed for 6 GHz hop and for 12 GHz multiply by 2 P_O values computed for the 6 GHz hop. Normally $P_O = 1$, when fade depth > 30 dB for 2600 seconds / one month. For any fade depth divide the seconds by 10 for every 10 dB deeper fade e.g. $P_O = 1$ fade depth > 40 dB for 260 seconds / one month. Other P_O values linear scaling (number of seconds proportional to P_O) is applicable.

2.3.4.3 General Formula for P_O Prediction

Several formulas have been proposed to predict the multipath occurrence factor P_O. They can be derived from the general formula, $P_O = C\,Q\,F^{a}\,L^{b}$ where F is the frequency in GHz, L is the hop length in km. The four parameters defining the prediction model are, a = Frequency Exponent; b = Distance Exponent; C = Climatic Factor and Q = Profile Factor.

2.3.4.4 Formula from ITU-R Rec. 530

The present issue of ITU-R Rec. 530 reports a formula for predicting the P_O factor in any radio link. The general P_O formula is specialized as follows:

a. Frequency Exponent a = 0.89;

b. Distance Exponent b = 3.6;

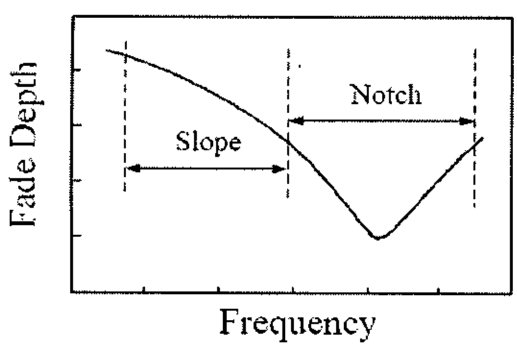
c. C is computed from rather complex tables, considering several conditions (inland or coastal links, fraction of the path profile near large or medium bodies of water; plain, hilly or mountainous terrain; latitude and longitude). As an example, for inland links $C = 0.01\ E\ pL^{1.5}$ where E = environment factor (in the range $2.2\ 10^{-8}$ to $5\ 10^{-6}$) and pL = % time with average refractivity gradient in the lowest 100m of the atmosphere less than -100 N-units/km (from maps in ITU-R Rec. 453);

d. $Q = (1 + \varepsilon)^{-1.4}$ where ε = slope (mrad) from Tx to Rx antenna.

The specific procedure for the computation of E is reported in ITU-R Rec. 530. In the above formulas C has the same role as K in Rec. 530, but C = 0.01 K, since in Rec. 530 the Rayleigh formula is expressed in %.

2.3.5 Frequency Selective Fading

The phase shift between signal echoes depends on frequency. As a result, the fade depth is varying with frequency (frequency selective fading). During multipath events, a signal bandwidth of some 20 MHz may be subject to slope distortion (fade depth maximum at one end and minimum at the other), or to notch distortion (maximum fade depth within the signal band).

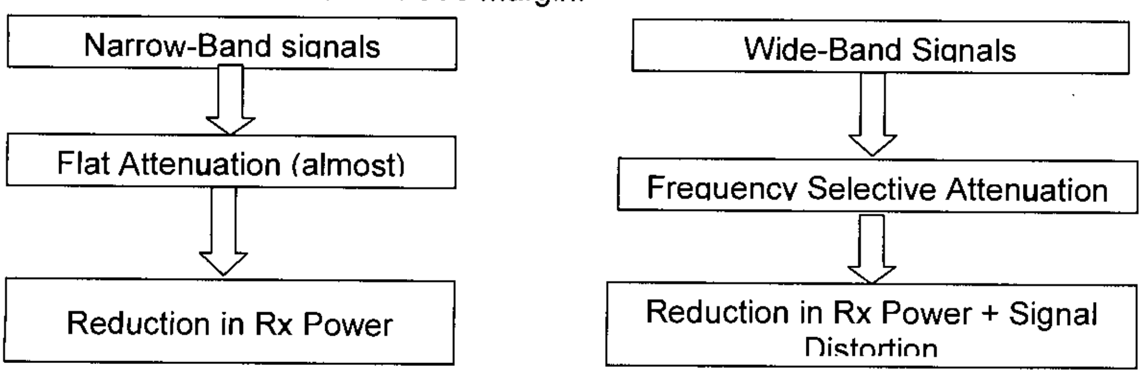


Amplitude distortion is associated to Group Delay distortion. Frequency selectivity is fast varying. This dynamic effect can be observed as a fast-varying slope or even as a fast moving notch trough the signal bandwidth.

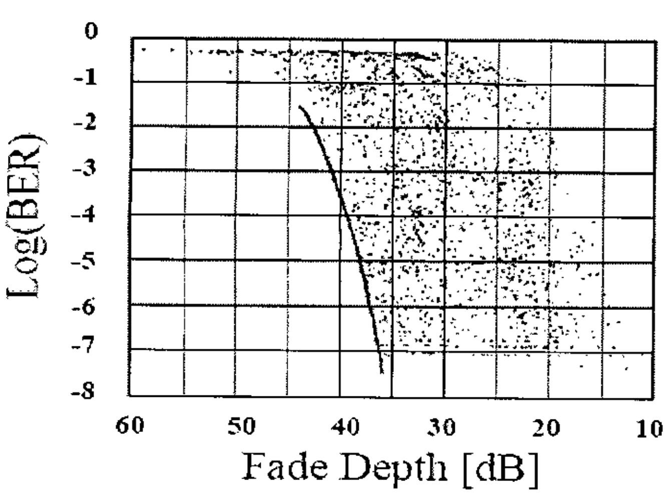
2.3.5.1 Effects of Frequency Selective Fading

If the signal bandwidth is narrow (few MHz), the selective fading effect is negligible. Multipath fading is assumed as a flat attenuation. On the other hand, for wide-band signals (medium and large capacity digital signals), the attenuation within the signal band produces a significant distortion in the received signal.

When a digital signal is distorted by selective multipath fading, the BER may be at the threshold level (10^{-3}) even if Rx power is higher than Rx threshold. The final effect is a reduction in Fade Margin.



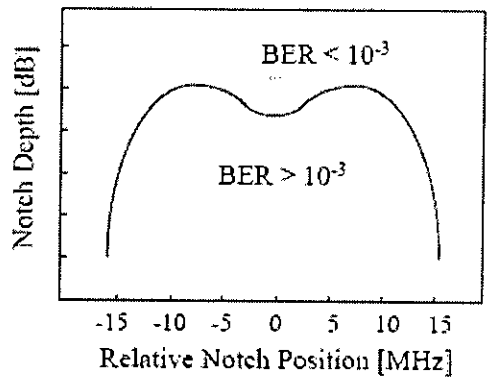
2.3.6 Effects of Multipath Distortions on Digital Signals



When a digital signal is distorted by frequency selective fading, BER may be greater than threshold (10^{-3}) even if Rx power is higher than Rx threshold.

In the figure, continuous line (BER vs. Fade Depth) is measured in the laboratory with a flat fading simulator (no signal distortion). The flat fade margin is 41 dB (fade depth corresponding to BER = 10^{-3}). The points at the right of the BER line are the result of field measurements, during selective fading. Each point is a measured BER, with the corresponding fade depth. BER threshold is reached even with 20 dB fade depth only. Continuous line denotes flat fading and indicates bit errors caused by noise only. Points on the right denote multipath selective fading and bit errors caused by the joint effect of noise and signal distortion.

2.3.7 Signature Measurement



The sensitivity of digital radio equipment to multipath distortions can be estimated by laboratory measurements. This is known to be equipment signature. The Tx signal passes through a simulated multipath channel, modeled by a direct path plus echo (2-path channel). This produces a frequency selective response: Notch Depth = Fade Depth (maximum) within the signal bandwidth; Notch Frequency = Notch Position, relative to the signal carrier. The Notch Depth and Frequency are varied (adjusting amplitude and phase of direct and echo signals). In each condition the BER is measured. In the notch depth / notch frequency plane, the signature gives the region (notch parameters) with BER > 10^{-3} (or any other threshold). The area below the signature gives a measure of the receiver sensitivity to multipath distortions.

2.3.8 De-Polarization due to Multipath

During Multipath events a reduction in the cross-polar discrimination (XPD) at the Rx antenna is observed. This is mainly related to the shape of the X-polar antenna diagram (usually with deep and sharp attenuation only in the maximum gain direction), quite different from the shape of the co-polar diagram. In most cases it has been observed that the XPD remains almost constant for signal fades up to about 20 dB, while it degrades 1 dB for dB for deeper fades. This suggests an approximate model for estimating the XPD reduction on the following basis:

a. Define XPD_0 as a fictitious unfaded XPD, better than the actual antenna XPD by some 15 to 20 dB;

b. For co-polar attenuation (CPA) deeper than 20-25 dB, estimate the probability of XPD reduction as:

$$\text{Prob}\{\, XPD < XPD_0 - A_0(dB) \,\} = \text{Prob}\{\, CPA > A_0(dB) \,\} \quad \text{......(2.19)}$$

ITU-R Rec. 530 reports a more sophisticated model, which takes into account also the use of an 'X-Polar Interference Canceller (XPIC)'. Moreover, it considers the transmission of the two cross-polarized signals by a single antenna, or by two space separated antennas (in last case the XPD reduction effect is in some measure relaxed).

2.3.9 Outage Time Prediction for Wide-Band Signals

With wide band signals, fading selectivity must be considered. Several statistical models have been proposed. Some are described in ITU-R Recs. A general formula for outage time T_{out}, during the observation period T_O, is:

$$T_{out} = T_O\, P_{OUT} = T_O\, [P_T + P_S] \quad \text{....................................... (2.20)}$$

Where, $P_T = P_O\, 10^{-FM/10}$ which is 'non-selective outage probability' (related to signal attenuation only; same as for narrow-band signals);

P_S = Selective outage probability (related to signal distortion) computed on the basis of the receiver signature (sensitivity to signal echoes).

An alternative formula for combining P_T and P_S is $T_{out} = T_O[P_T^{\alpha/2} + P_S^{\alpha/2}]^{2/\alpha}$ where α = 1.5 - 2 is an empirical constant.

2.3.10 Maximum Hop Length (Rain & Multipath)

Maximum hop length in point-to-point radio links can be estimated on the basis of the following assumptions:

a. Multipath outage must be below the error performance objective; rain unavailability below 1/3 of the unavailability objective (2/3 assigned to equipment failures).

b. Objectives are allocated proportionally to the hop length. For very short hops at 23 GHz a fixed unavailability objective have been adopted. These objectives are from ITU-R Recs.557 (availability) and 594 (error performance).

c. For propagation following have been considered:

   (1) ITU-R rain prediction model for different rain regions (K, L. N, P);

   (2) Multipath occurrence factor, $P_o = 4x10^{-7} FL^3$ where F = freq. in GHz and L = hop length in km (corresponding to temperate climate with average-to-bad terrain)

   (3) Space diversity with 8 m antenna spacing.

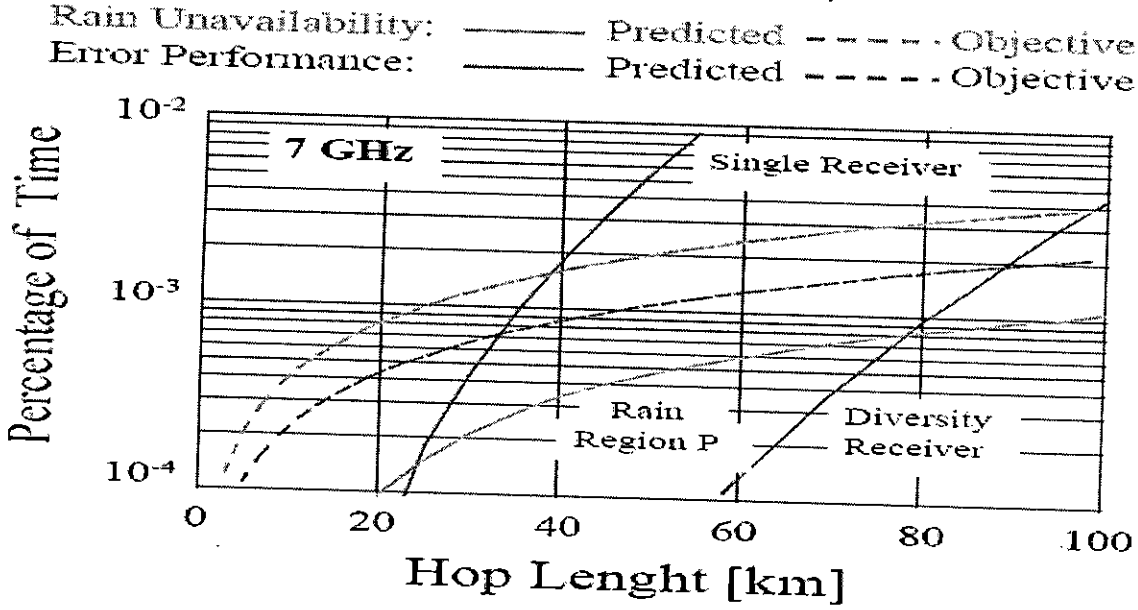
Results are given for high capacity systems at 7, 13, and 23 GHz. Equipment and antenna assumptions are:

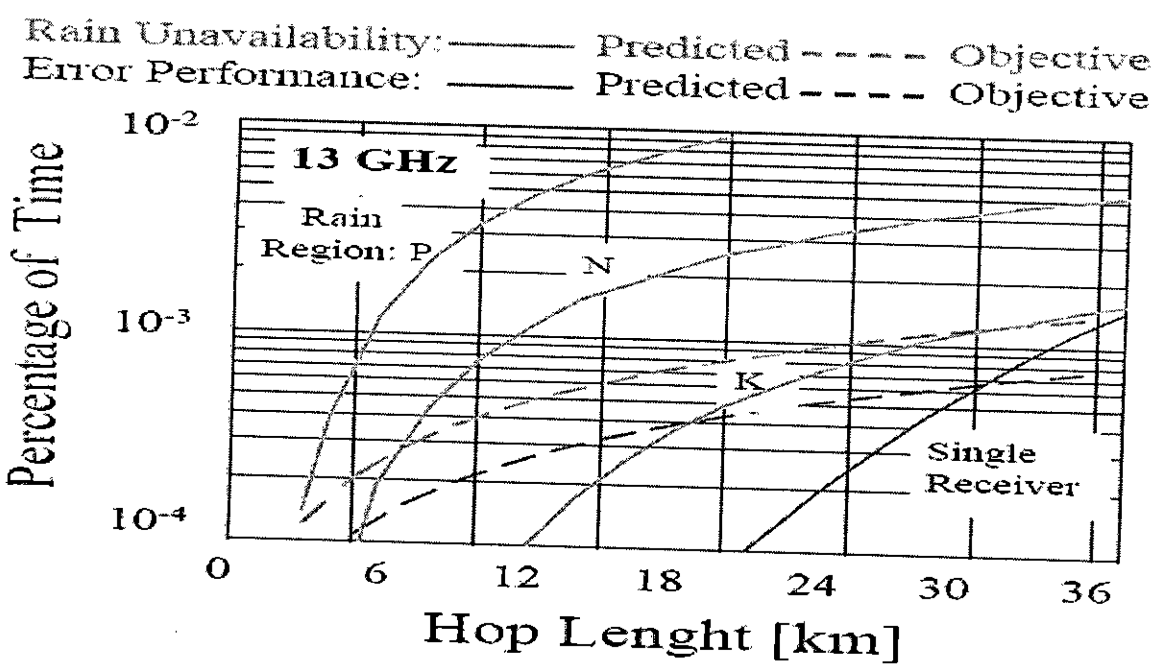
a. For 7 GHz system 100 dB system gain; 3.0 m antenna (44.5 dB gain) and 3 dB additional losses.

b. For 13 GHz system 100 dB system gain; 3.0 m antenna (48.8 dB gain) and 3 dB additional losses.

c. For 23 GHz system 90 dB system gain; 0.6 m antenna (40.5 dB gain) and 3 dB additional losses.

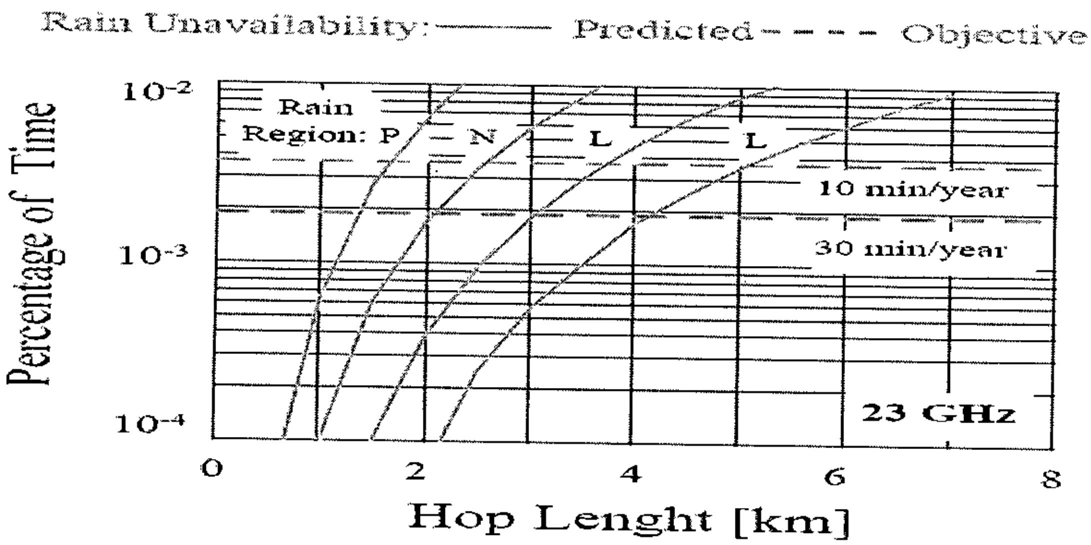
Maximum Hop Length (Rain & Multipath) 7 GHz





Maximum Hop Length (Rain & Multipath) 13 GHz

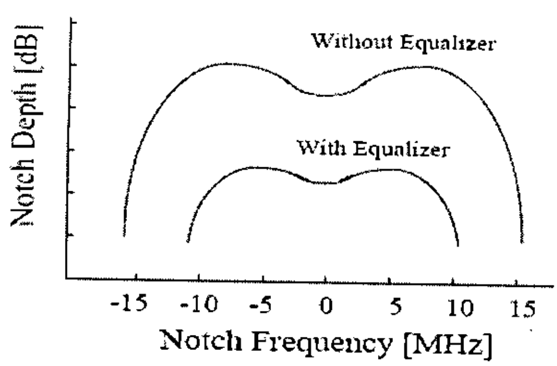
Maximum Hop Length (Rain & Multipath) 23 GHz



2.3.11 Multipath Countermeasures

Techniques used to reduce the multipath fading impairment in digital systems are adaptive signal equalization at the receiver and diversity receptions i.e. space diversity, angle diversity and frequency diversity. For each multipath countermeasure, the improvement factor (IF) is defined as: IF=T_{out} (Unprotected) / T_{out} (with Countermeasure) where T_{out} = outage time. The improvement factor can be predicted by means of statistical models including the effect of each specific countermeasure. When both equalization and diversity are used, the overall improvement factor is approximately given by the product of the factors relevant to each technique (Synergistic Effect).

2.3.11.1 Adaptive Equalization



Adaptive equalizer is a circuit used at Rx, to partially compensate for signal distortion. Adaptativity means that the equalizer response modifies, depending on the received signal. In the intermediate frequency (IF) implementation, the equalizer amplifies the spectral components more deeply attenuated by fading. In the base band (BB) implementation, the equalizer cancels from each signal sample the component due to intersymbol interference (ISI). This technique is usually more effective. The effectiveness of a signal equalizer can be appreciated by comparing the receiver signatures with and without the equalizer. The reduction in the area below the signature curve gives a measure of the improvement provided by the equalizer.

2.3.11.2 Equalization Improvement

The reduction in 'multipath outage time' provided by equalization is estimated by comparing the Rx signatures with and without the equalizer. The equalizer improvement factor (IF_E) is defined as the ratio of the 'selective outage probability (P_S)' without and with the equalizer i.e. $IF_E = P_S$ (unequalized) / P_S(equalized). According to ITU-R Rec. 530 model, selective outage probability (P_S) is proportional to signature area (A_S) and defined as $A_S = W\ 10^{-B/20}$ where W = signature width (GHz) and B = signature depth (dB). So, equalizer improvement factor (IF_E) can be estimated as $IF_E = A_S$ (unequalized) / A_S (equalized).

2.3.11.3 Space Diversity

Two antennas are usually arranged on a single structure with a suitable vertical spacing. Typical spacing is 150 - 200 wavelengths. The correlation of fade depth at the two antennas decreases as the antenna spacing increases. Thus the probability of deep fading at the two antennas at the same time can be made sufficiently low with suitable antenna spacing. The relation between antenna spacing and correlation in signal distortion is more controversial. It appears that also with small spacing a low correlation is obtained. The techniques of signal processing are either switch to the best signal or combine both the signals where at both the cases the objective is to get maximum power with minimum distortion and the implementation is done at RF, IF or BB.

2.3.11.4 Angle Diversity

Some space diversity experiments have led to the conclusion that the diversity improvement in signal distortion seems to be independent of the antenna spacing. Even if this point is, in some way, controversial, it suggests the possibility of getting a diversity improvement also with angle diversity. Two implementations of angle diversity are considered:

a. Antenna Diversity: Two antennas (of the same type or of different types) side by side with slightly different pointing angles (used in preliminary experiments).

b. Beam Diversity: One antenna with two feeders, producing beams with different shapes and/or pointing.

In both cases, two beams operate at the receiver, closely spaced, but with different shapes. The multipath components are subjected to different weighting at the two beams and the two composed Rx signals are in some measure uncorrelated. The advantages are lower costs and no need of high / complex tower structures i.e. only one antenna with beam diversity serves the purpose. On the contrary the disadvantages are less diversity improvement and less experience in outage prediction models.

2.3.11.5 Frequency Diversity

Multipath fading is frequency selective. In multi-channel radio systems (usually with about 20 - 30 MHz spacing), not all the RF channels are deeply faded at the same time. An RF stand-by channel is usually available (in 1+1 or N+1 arrangement) for equipment failure. It can be exploited also for multipath protection. The traffic of a low quality (deeply faded) working channel can be switched to the stand-by channel, with high probability of a significant quality improvement. In some cases, the stand-by channel can be in a different RF band (cross band frequency diversity). Example: 7 GHz system with 11 GHz protection. For frequency diversity fast quality detector and switching circuits are required. Normally this is 'Hitless Switching' i.e. without errors or frame loss caused by the switching itself.

2.3.11.6 Diversity Improvement

The Diversity Outage Probability for narrow-band signals (P_{DT}, Non-Selective Fading Model) is given by $P_{DT} = P_T / IF_D$ where P_T = Non-selective outage probability, single receiver = $P_o\ 10^{-FM/10}$; P_o = Multipath fading occurrence factor; FM=Fade margin and IF_D=Diversity improvement factor. Therefore IF_D is estimated as under:

a. For space diversity, ITU-R Rec. 530 gives the improvement factor IF_{SD} at fade depth A (dB) as:

$$IF_{SD} = [1 - \exp(-3.34\ 10^{-4}\ S^{0.87}\ F^{-0.12}\ L^{0.48}\ P_o^{-1.04})]\ 10^{(A - V)/10} \quad \text{..... (2.21)}$$

Where S = vertical spacing (m) of Rx antennas (centre-to-centre); F = frequency (GHz); L = hop length (km) and V = absolute difference of the two antenna gains (dB).

b. For frequency diversity (1 + 1 configuration), ITU-R Rec. 530 gives improvement factor (IF_{FD}) at fade depth A (dB) as:

$IF_{FD}=(80/FL)\ (\Delta F/F)10^{A/10}$ where ΔF = Frequency spacing (GHz) ...(2.22)

Therefore 'diversity outage probability' due to selective fading only (P_{DS}) is given by $P_{DS} = P_S^2 / \eta(1 - k_S^2)$ where P_S = selective fading outage probability with single receiver; k_S = selective correlation coefficient; formulas for the computation of k_S with space and frequency diversity are rather complex.

2.3.12 Propagation through Ducts

In extreme cases, atmospheric layering may be such that radio propagation is confined within a sort of waveguide (radio duct). Ducts are classified as:

a. Surface Ducts: If the lower boundary of the duct is the earth surface, then it is called 'Surface Duct'.

b. Elevated Ducts: If the lower boundary of the duct is above the earth surface, then it is called 'Elevated Ducts'.

Duct propagation is characterized by attenuation well below the free space value. So, if the Rx antenna is within the duct, the Rx signal may be much higher than in normal conditions. On the other hand, if the Rx antenna is out of the duct, rather long signal fading are observed. Duct propagation may be also responsible of unexpected interference at very long distance. There is no general approach for a statistical prediction of duct events. However, in specific cases, the analysis can be based on the identification of refraction conditions leading to the duct formation. Then, if statistical local data on refractivity gradient distribution are available, the ducting probability can be estimated.

2.4 Ground Reflections

Depending on the path profile, it may happen that a portion of the Tx radio signal is reflected by the ground toward the Rx antenna. At the receiver, in addition to the direct signal (D), a reflected signal (R) arrives. In most cases, the presence of a ground reflection is rather critical for following reasons:

a. Fluctuations in the Rx signal level, even for long time periods.
b. Enhancement of multipath activity (the reflected signal is not added to a stable direct signal, but to the fast-varying multipath signal).
c. Reduction of space diversity effectiveness as a countermeasure to multipath.

Therefore as far as possible, reflections should be avoided by route planning in particular over-water paths and site selection. Obstruction of the reflected ray can be obtained in some cases, by suitable selection of the radio sites and of antenna heights.

2.4.1 Reflection Coefficients

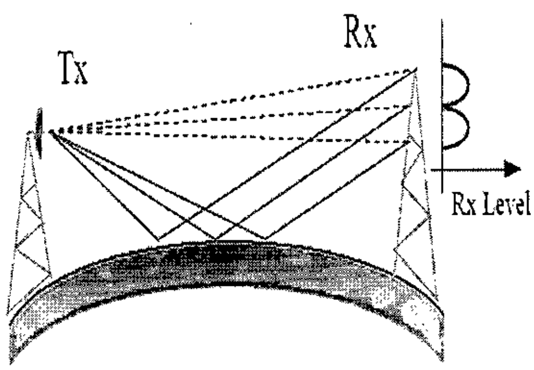
In many cases it is advisable to adopt the conservative assumption that the modulus of the reflection coefficient be equal to 1. For very small grazing angles and / or for horizontal polarization, this is a realistic approximation. For vertical polarization, the table gives the reflection coefficient modulus in the case of sea reflection:

Frequency	Grazing Angle 0.5°	1°	2°	4°
1 GHz	-1.4 dB	-2.8 dB	-6.2 dB	-12.0 dB
3 GHz	-1.2 dB	-2.3 dB	-5.3 dB	-10.9 dB
10 GHz	-0.8 dB	-1.7 dB	-4.3 dB	-8.4 dB

Similarly, the phase of the reflection coefficient is very close to 180° with horizontal polarization (any grazing angle) and also with vertical polarization for grazing angles below 0.5°. With vertical polarization and larger grazing angles, the phase is smaller than 180°, depending also on the frequency. However, in radio link design, the prediction of the reflection coefficient phase is usually not required.

2.4.2 Rx Signal Level

If the antenna height is varied, then the path length difference and the phase shift between the direct and the reflected signal change. As a result, the Rx signal level is a function of the antenna height.



When direct and reflected signals are co-phased then the Rx signal level is the maximum. Again when direct and reflected signals are phase-opposed then the Rx signal level is the minimum. The exact positions corresponding to the maximum and minimum Rx level change with propagation conditions (k-factor).

2.4.3 Space Diversity in Reflection Paths

The Rx level varies with the antenna height, but the position of the maximum Rx level is not stable, due to varying propagation conditions (k-factor). With two antennas, a good Rx level can be expected at least at one antenna. Therefore space diversity engineering depends on the following factors:

a. Antenna spacing whose optimum value is computed, but again it depends on the k-factor. The design rule is to compute spacing for k=4/3 and to check for higher and lower k-factors.

b. Position of the lower antenna which should be as low as possible in general in order to obstruct (at least partially, if possible) the reflected ray and minimize path difference and reflected signal delay.

c. Clearance i.e. for the lower antenna, in most cases, clearance = 0 is enough and usual rules for the higher antenna.

Therefore implementation options open are either BB switching to the best signal or RF / IF adaptive combining (as for multipath countermeasure) or RF combining (anti-reflection system).

2.4.4 Anti-Reflection System

Space diversity as a reflection countermeasure, is usually implemented to maximize Rx power level by switching to the best signal or combining in IF or RF. Maximized Rx signal is in some way a combination of the direct and the reflected signal. In some cases it is required that the reflected signal be cancelled, to avoid signal distortion (particularly with very long reflection delays). The anti-reflection system is an RF space diversity implementation with the objective of canceling (or minimizing) the reflected signal component in the overall Rx signal. The antenna spacing is such that the reflected signal arrives in phase opposition at the two antennas. The space diversity configuration can also be seen as an antenna array, with an overall directivity pattern having a null toward the reflection point. Also the anti-reflecting systems, as other space diversity implementations, are usually optimized for standard propagation conditions. Then the solution is checked in the whole range of expected k-factor values.

2.4.5 Effect of Echo Delay

The reflected ray delay (τ) must be compared with the symbol period (T_S) of the digital signal. Depending on τ and T_S, the reflection effects are:

a. If $\tau << T_S$ then no distortion occurs. The variation in the Rx signal level without frequency selectivity in the signal bandwidth is insignificant and this is the most frequent condition.

b. If τ < or = T_S then frequency selective attenuation occurs within the signal bandwidth. The maximum in-band dispersion (notch) depends on the reflected signal level and a measure of the Rx sensitivity is given by the 'equipment signature'.

c. If τ > Ts then it is similar to external co-channel interference, since the reflected signal is uncorrelated to the direct one. The equipment BER vs. C/I curve gives a measure of the relevant degradation. This is a very rare condition.

2.5 Propagation through Rain

Main phenomena associated to radio propagation in the presence of rain are scattering, absorption and de-polarization. Scattering is the part of the EM energy which is re-irradiated by the raindrops in every direction. Absorption is the part of EM energy which is transferred to water molecules in the raindrops. And when polarization plane (e.g. vertical) of the incident radio signal is rotated, a cross-polarized component (e.g. horizontal) in the signal at the receiver is thus produced. This is known as de-polarization. These phenomena are sensitive to signal frequency (wavelength compared to the drop size), signal polarization (this is related to not-spherical drop shape) and rain intensity.

2.5.1 Radio Wave Propagation through Rain

In passing through a region containing precipitation, an EM wave is attenuated by two phenomena. Firstly energy is scattered out of the desired direction and secondly energy is absorbed and thereafter converted into heat. The total power lost P_{LOST} in the impact with a raindrop is $P_{LOST} = P_{INC}\ Q(r, \lambda)$, where P_{INC} is the incident power and Q is called the drop cross section, which is a function of the drop radius r and of the signal wavelength λ. The drop cross section Q can be considered as the sum of a scattering cross section and an absorption cross section. The above formula can be integrated in a volume (called a rain cell), in order to estimate the total loss produced within that rain cell. The integral extends to the raindrops contained in that volume. The integrand function Q depends on the drop size (radius r in the formula). This integral can be solved by means of statistical models, relating the number of drops and their size distribution to the intensity of rain precipitation. On the basis of such models, with a large amount of experimental data, the exponential formula, $\gamma = k R^{\alpha}$ has been derived, giving the specific rain attenuation γ (dB / km), as a function of the rain rate R (mm/h). Factor k and exponent α are given in ITU-R Rec. 838 as functions of frequency and wave polarization (horizontal or vertical). Formulas in the same recommendation also include the cases of any linear or circular polarization and the effect of path elevation angle. The above discussion applies to rain attenuation within a rain cell, with uniform rain intensity. The real situation is that of a radio path, whose length is usually (much) greater than the average cell size. In order to represent the effect of spatial variation in rain intensity, most prediction models make reference to an 'Effective Path Length L_{EFF}', depending on the real path length and on assumptions on the rain distribution along the path. For very short paths, L_{EFF} becomes equal to the real path length. The ITU-R model for rain unavailability prediction is based on these concepts.

2.5.2 De-Polarization due to Rain

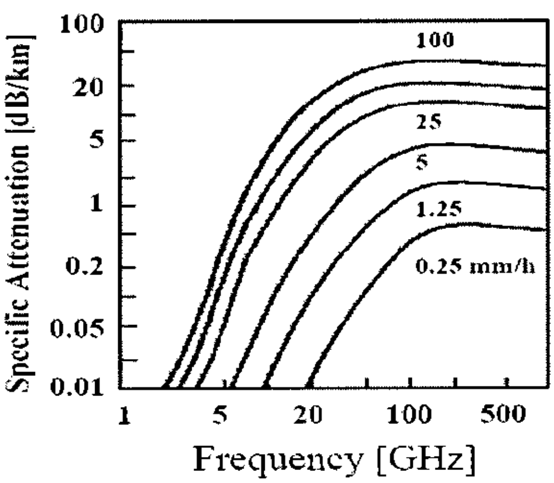
A polarized signal passing through raindrops is subjected to a partial rotation of its polarization plane. This is produced by the non-spherical shape of raindrops and the canting angle in raindrop fall (caused by wind generally present during storms). According to ITU-R Rec. 530, an equiprobability relation can be established between the Co-Polar signal Attenuation (CPA, in dB) and the Cross-Polar Discrimination (XPD) during intense rain periods:

$$XPD\ (dB) = U_0\ 30\ Log10\ F - 20\ Log10\ CPA \quad (2.23)$$

where U_O = 15 dB (average, lower bound 9 dB) and F = Frequency in GHz. The uncertainty in the Uo value makes not significant difference between H and V pol. attenuation. CPA can be assumed as an average value. Other validity limitations are frequency in the range $8 < F < 35$ GHz and small path elevation angle. The above formula (equiprobability relation) means that the probability of attenuation higher than CPA value is roughly equal to the probability of cross-polar discrimination lower than the XPD.

2.5.3 Rain Attenuation

A radio wave traveling through rain drops is subjected to scattering and absorption phenomena. In this process, part of the signal energy directed to the receiver is lost. The rain attenuation is measured in dB/km. It increases with frequency, but can be assumed as uniform (flat) within a radio channel bandwidth. It also increases with rain intensity and is higher with horizontal polarization than with vertical polarization. It produces fades usually several minutes long.

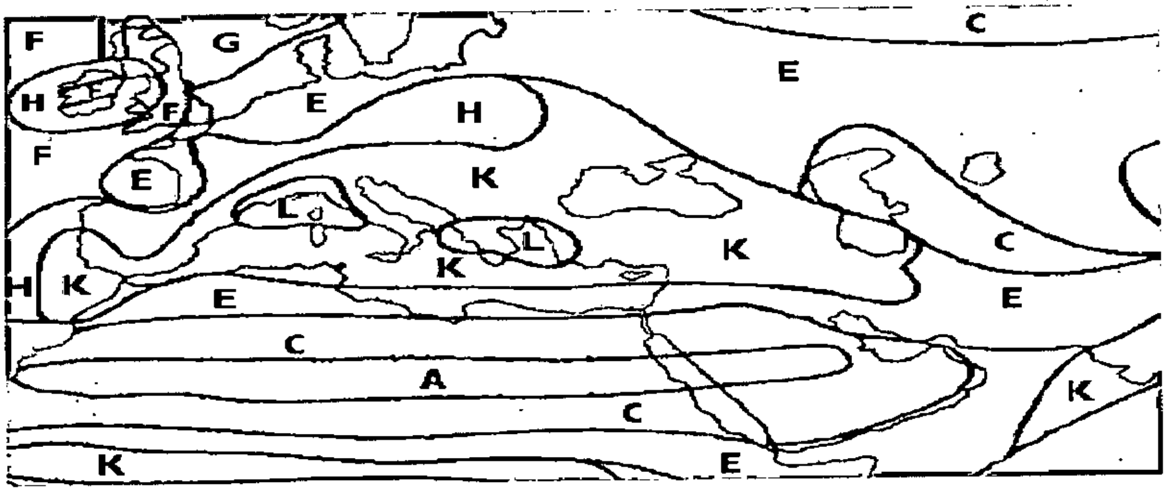


2.5.3.1 ITU-R Rain Regions

In temperate climates, frequencies below 10 GHz are not significantly affected by rain. On the other hand, in tropical climates rain effects are to be considered even at 5 ~ 6 GHz. The ITU-R provides a world map of rain regions. For each region, the rain rates (mm/h) for given time percentages are reported. 'Rain

Attenuation Models' make reference to rain rates corresponding to small time percentages (0.01 %).

2.5.3.2 Rain Rates in ITU-R Regions



The rain rate R (mm/h) for 0.01% of time is used in the ITU-R Rain Attenuation Model, in order to predict rain unavailability. The rain rate in the rain regions specified in ITU-R maps are:

Rain Region	Rain Rate (mm/h)	Rain Region	Rain Rate (mm/h)
A	8	H	32
B	12	J	35
C	15	K	42
D	19	L	60
E	22	M	63
F	28	N	95
G	30	P	145

2.5.3.3 ITU-R Rain Attenuation Model

A step-by-step procedure is recommended by ITU-R:

a. Find rain rate (R) for 0.01% of time (from ITU-R maps, or from local data).

b. Compute specific loss (γ) (dB/km) corresponding to rain rate R and to wave frequency and polarization (H or V) (formulas are given by Rec. 838).

c. Compute effective hop length L_{eff} (km) (real length is reduced, taking into account the rain cell size) (formulas are given by Rec. 530).

d. Compute the attenuation for p = 0.01% of time: $A_{0.01}$ (dB) = γL_{eff}.

e. The attenuation for other time percentages (in the range 1% to 0.001%) is computed from $A_{0.01}$, (formulas are given by Rec. 530).

2.5.3.4 ITU-R Model for Rain Unavailability Prediction

Considerations for the model are rain rate, specific loss and effective hop length. In the absence of local data, an estimate of the rain rate (R) (mm/h) for 0.01% of time can be obtained from data in the ITU-R maps (Rec. 837). Specific loss (γ) (dB/km) = $k R^{\alpha}$ where k and α are functions of frequency and of wave polarization. Some examples (valid for small path elevation angles) are:

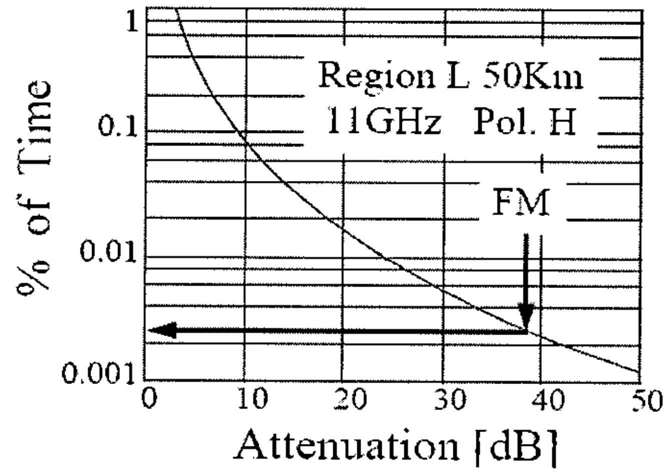
Frequency [GHz] / Polarization

	10 / H	10 / V	20 / H	20 / V	30 / H	30 / V
k	0.0101	0.00887	0.0751	0.0691	0.187	0.167
α	1.276	1.264	1.099	1.065	1.021	1.000

A table with k and α values from 1 to 400 GHz is reported in ITU-R Rec. 838, which includes formulas for taking into account also path elevation angles and circular polarization. And effective hop length (L_{EFF}) = r L where L = actual hop length and r = distance factor. The value of r = 1 / (1 + L / {35 exp [-0.015 R)]} if R < 100 mm/h and r = 1 / (1 + L / 7.81) if R >= 100 mm/h. Attenuation for p = 0.01% of time i.e. $A_{0.01}$ (dB) = γL_{EFF}. Therefore attenuation for any time percentage p (in the range 1% to 0.001%), A (dB) = $0.12 A_{0.01} p^{-(0.546 + 0.043 \text{Log10 } p)}$. The ITU-R prediction method is considered to be valid for frequencies up to 40 GHz and hop lengths up to 60 km.

2.5.4 Rain Unavailability Prediction

From the time % vs. rain attenuation curve, the unavailability is computed as the time percentage with attenuation greater than the fade margin.



In the figure a 38 dB fade margin is assumed. Then the rain unavailability is about 0.0025% (about 12 minutes / year). The prediction method derives from long term rain rate statistics. Therefore, the rain unavailability prediction must be considered as an average, to be expected during a period of several years.

2.5.5 Other Rain Impairments

Other rain impairments are effects of de-polarization and scattering. Effects of de-polarization are as under:

a. In radio links using the co-channel plan (two cross-polar radio channels at the same frequency), the C/I ratio is guaranteed by the isolation between H and V polarizations. In the absence of rain, the antenna XPD can provide a C/I ratio well above 25 dB.

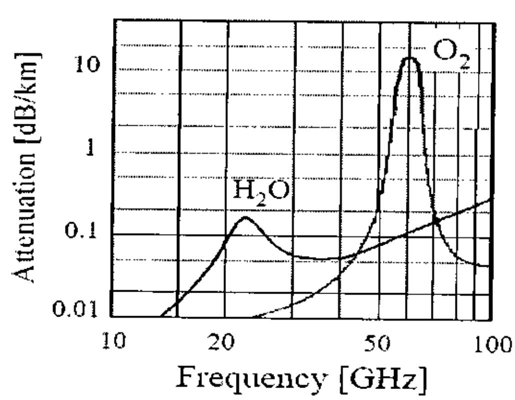
b. Rain de-polarization reduces the C/I ratio at the receiver. A statistical model is proposed by ITU-R Rec. 530. For example in a 13 GHz link, with 40 dB rain attenuation, the XPD is reduced to about 16 dB (according to the ITU model). While an increase in Tx power (and in fade margin) reduces rain unavailability due to rain fading, it is of no help for rain de-polarization.

The scattering of radio wave energy produced by rain drops may cause interference to other radio systems. This effect is particularly significant with high Tx power (e.g. interference from satellite earth stations to radio-relay links). The procedures for the evaluation of the co-ordination area around earth stations (ITU-R Rec. 615) include an estimate of this effect.

2.6 Other Hydrometeor Effects on Propagation

Apart from rain, other hydrometeors that may impair radio communications are snow, hail and fog. Dry snow has no significant impact at least for frequencies below 30 GHz. On the other hand, very wet snow can produce, in extreme cases, signal attenuation even at frequencies usually not affected by rain phenomena. The probability of such events, however, is generally small. The most important effect of snow is the possible ice build-up on the antenna reflectors, thus modifying the antenna performance. For this reason, radomes are often installed. Large earth station antennas for satellite communications are usually protected with anti-ice devices. The hail effect is similar to rain, but strongly dependent on the dimension of ice spheres and very less significant effects are observed at frequencies above 30 GHz. On the other hand the specific attenuation γ due to fog is γ (dB / km) = K M where K is the specific attenuation coefficient in (dB/km)/(g/m3) and M is the liquid water content of fog in g/m3 (with very thick fog M = 0.5 g/m3). At 30 GHz, K = 0.5 ~ 1 (depending on temperature), so the specific attenuation γ is expected to be not higher than 0.5 dB / km in any case. At frequencies above 100 GHz, K is about ten times greater than at 30 GHz. More information is in ITU-R Rec. 840.

2.7 Atmospheric Absorption



The power loss caused by atmospheric absorption is usually not significant and can be neglected in the link budget. Only in particular frequency bands this effect is to be considered. Frequency bands affected by atmospheric absorption peaks are 22.5 GHz (by water vapour and maximum attenuation is 0.18 dB/km) 60 GHz (by oxygen and maximum attenuation is 16 dB/km). The figure is valid for a temperature rating of 15 °C, water vapour rating of 7.5 g/m^3 and at sea level.

2.7.1 Use of Frequency Bands - 22.5 GHz and 60 GHz

Radio systems operating in the 22 ~ 23 GHz bands are only marginally affected by atmospheric absorption. In temperate climates, hop lengths are generally limited below 10 ~ 12 km because of rain attenuation. The additional attenuation due to water vapour absorption is small (2 to 3 dB depending on temperature and humidity), but is to be considered in the link budget. The 60 GHz band is not presently in commercial use. It could be used for very short hops e.g. building-to-building links. The very high attenuation at 60 GHz allows the re-use of the same RF carrier within a short distance, without mutual interference (small re-use distance). A high efficiency in spectrum utilization can be achieved.

2.8 Summary

Basing on the radio propagation physics, basic concepts of radio link engineering and other related issues following can be assumed:

a. Only atmospheric multipath and rainfall has got significant effects on path performance for frequency band less than 13 GHz.

b. Other issues have significant effect for frequency band more than 13 GHz.

c. All calculations can provide an engineering estimate of performance but its accuracy will depend on the accuracy of the path survey report.

END OF CHAPTER

CHAPTER 3
PERFORMANCE TARGET AND SYSTEM DESIGN REQUIREMENTS

3.1 Introduction

This chapter describes the fundamentals of ITU transmission performance standard, use of RF band, system design requirements and the scope of work to meet the design and performance requirements of microwave digital radio networking system.

3.2 Related Terms and Regulatory Issues

Target states rules those can allow efficient transport of information between two or more locations using real connections. Parameters are the entities to be measured. Objectives allow to derive the parameter limits in a given time interval. Organizations / institutions responsible for recommendations / standards are ITU-T (ex CCITT) for all systems for all over the world, ITU-R (ex CCIR) for radio systems only for all over the world and ETSI for all systems for Europe only. The regulatory bodies deal main topics relevant to digital radio relay systems and the regulatory issues are performance objectives and use of RF bands.

3.3 Performance Objectives

There are two sets of objectives to determine the performance of a digital network i.e. error performance objectives and availability objectives. For digital networks both objectives are recommended by the ITU-T, regardless of the transmission medium. The pertinent ITU-T recommendations are taken into account in producing the ITU-R error performance and availability recommendations, which are specific for the case of digital radio relay systems.

3.3.1 ITU-T Performance Objectives and Recommendations

Error performance objectives are based on quality parameters e.g. BER, SES and maximum time percentages for each quality parameter below given thresholds. There are two definite recommendations in relation to the error performance objectives i.e. Rec. G.821 and Rec. G.826. As per Rec. G.821 the error performance is based on errored bit measurements at a bit rate below the primary rate. Errored second (ES) is defined as a one-second period with one or more errored bits and SES as a one-second period with BER ≥ 10^{-3}. For 27,500 km hypothetical reference connection (HRX) as a part of an ISDN network, the objectives are number of ES per second in total available time should be less than 0.08 and number of SES per second in total available time should be less than 0.002. As per Rec. G.826 the error performance is based on errored block measurements at a bit rate at or above primary rate. Block is defined as a set of consecutive bits, with size depending on bit rate. ES is a one-second period with one or more errored blocks and SES is a one-second period which contains ≥ 30% of errored blocks or at least one defect. Defect is a loss of signal, AIS, LOF for PDH; more complex for SDH and ATM. And background block error (BBE) is an errored block not as part of a SES and is used only in G.826. For 27,500 km hypothetical reference path (HRP), PDH and SDH transport networks and cell based (ATM) connections, the objectives are:

a. No. of ES / Sec. in total available time < (0.04-0.16);

b. No. of SES / Sec. in total available time < 0.002;

c. No. of BBE / No. of blocks in available time (less SES) < 0.0004.

Availability objectives are based on available time and maximum unavailable time percentage. Availability may be outlined as; say after 10 consecutive SES events, unavailability is detected. So these 10 seconds are part of the unavailable time. But after 10 consecutive non-SES events, availability is detected. Therefore these 10 seconds are part of the available time. Point to note that the error performance objectives are checked only during available time. ITU-T objective and related Rec. G.827 on availability are presently under study.

3.3.2 ITU-R Performance Recommendations

ITU-R performance Recs. are in transition to be updated to recent ITU-T Recs. G.826 (error performance) and G.827 (availability). Presently, G.827 final objectives are under study.

3.3.2.1 Status Ante G.826 / G.827

For availability objectives, Rec. 557 for hypothetical reference digital path (HRDP) and Rec. 695 for real digital radio relay links (high grade) are applicable. And the basic objective for 2500 km high grade systems is to obtain unavailability ≤ 0.3%. Unavailability is usually measured on a one year basis, but objectives should be satisfied as a multiple year average. Unavailability is normally produced by slow propagation impairments (U_p), rainfall (U_r) and equipment failure (U_f). For well engineered path (free space condition) and normal propagation, U_P is considered to be negligible. Usually following apportionment of overall objective is adopted:

Frequency Bands (GHz)	U_r	U_f
Below 7	-	Total
7/8 – 11	1/3	2/3
11 – 15	2/3	1/3
> 18	Total	-

For error performance objective, Rec. 594 for HRDP and Rec. 634 for real digital radio relay links (high grade) are applicable. The basic objective for 2500 km high grade systems is to obtain BER ≤ 10^{-3} for less than 0.054% of available time.

3.3.2.2 Status Post G.826 / G.827

For availability objective, new ITU-R Rec. G.827 is under study. For error performance, Rec. 1092 and 1189 for digital radio system in international and national portion of a 27,500 km HRP are applicable respectively. The basic objective for a 50 km hop in the international portion of HRDP is SES percentage not greater than 2 ~ 4 x 10^{-4} % (5 ~ 10 seconds / month, depending on overall objective allocation, block allowance, etc).

3.4 Use of RF Bands

The international radio regulations define the type of radio services operating in each RF band on a primary or secondary status. For the RF bands assigned to the terrestrial fixed radio service, the ITU-R recommends the adoption of frequency plans, with detailed specification of the RF carrier position, channel spacing and guard bands etc.

3.4.1 RF Bands Assigned to the Radio Fixed Service

The frequency bands allocated by radio regulations to radio relay systems (fixed service in the radio regulations terminology) are:

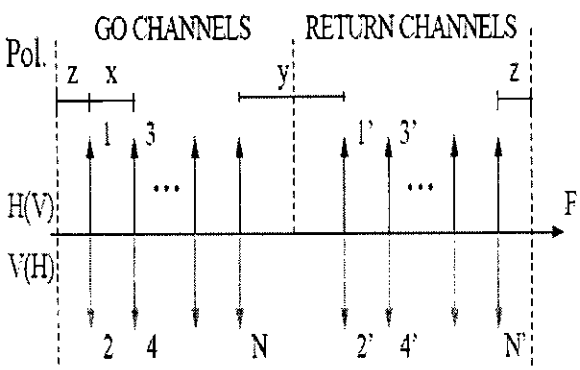
0.440 - 0.470 GHz	5.850 - 8.500 GHz	21.200 - 23.600 GHz
0.806 - 0.960 GHz	10.500 - 10.680 GHz	25.250 - 29.500 GHz
1.427 - 1.525 GHz	10.700 - 11.700 GHz	36.000 - 40.500 GHz
1.700 - 2.690 GHz	12.750 - 13.250 GHz	47.200 - 51.400 GHz
3.400 - 4.200 GHz	14.300 - 15.350 GHz	54.250 - 58.200 GHz
4.400 - 5.000 GHz	17.700 - 19.700 GHz	59.000 - 64.000 GHz

Many of the above bands are further sub-divided among different classes of users, on a national or international basis. The ITU-R gives detailed channel arrangements for most of these bands. Additional indications are provided for particular conditions or exceptions relevant to some countries or group of countries. Therefore the above list is to be intended just for general information.

3.4.2 ITU-R Recommended Frequency Plans

Separate sub-bands are allocated for Tx and Rx channels with a central guard band (only exception with U.S. TD 4 GHz plan, with alternate Tx and Rx channels) and constant channel spacing between co-polarized channels are maintained. Two types of channel arrangements are recommended e.g. interleaved plan and co-channel plan. Criteria followed in the ITU-R frequency plan activity are compatibility of channel arrangements in the transition from analog to digital systems below 12 GHz and optimization of channel arrangements for digital systems above 12 GHz.

Interleaved ch arrangement is recommended in analog systems but frequency reuse is not possible and adopted also for digital systems below 12 GHz.



x = Co-polar channel spacing; y = Central guard band; z = Edge guard band. Interferences is likely to occur between two adjacent X-pol. signals with channel spacing ΔF = x/2 and two adjacent co-pol. signals with channel spacing ΔF = x.

Fig -3.1 Interleaved Channel Arrangement

Co-channel arrangement is suitable for digital systems, short hops, simple modulations and recommended in frequency bands above 12 GHz (only digital). Recently it is also adopted in some frequency bands below 12 GHz but x-pol. interference canceller is required for complex digital modulations.

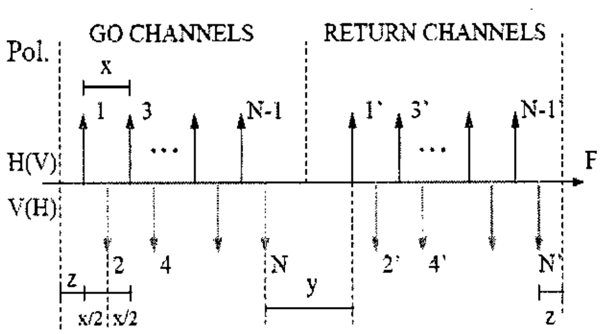


Fig 3.2 - Co-Channel Arrangement

x = Co-polar. Ch spacing, y = Central guard band and z = Edge guard band. Interferences is likely to occur at one x-pol. signal at the same frequency (ΔF = 0), between two adjacent co-pol. signals with channel spacing ΔF = x and between two adjacent x-pol. signals with channel spacing ΔF = x.

3.5 Design and Installation Requirements

A microwave radio system can be designed utilizing a loop and line configuration. Following issues must be addressed, specified and managed in order to achieve a successful implementation of the microwave radio system:

3.5.1 Site Selection, Connectivity and Traffic Requirements

Determine the required number of sites and an efficient point-to-point routing configuration to connect them. Assess impact of site location, availability, governmental regulations, permit requirements and construction costs. Identify the system hub site. The hub is the central point for the system. A traffic (voice and data) routing plan should be developed to designate circuit quantities and types at each location in the system.

3.5.2 System Operating and Monitoring Capabilities

An alarm system to support the microwave system and ancillary site equipment is required. The master alarm system should be located at a surveillance center or dispatch center staffed 24 hours per day and seven days per week. Consideration for a secondary monitoring point for a local maintenance shop is advisable.

3.5.3 Link or Path Reliability Standards

Typically, microwave links are engineered to provide a certain level of performance reliability against SES that can potentially drop traffic because of short-term multi-path fading events lasting less than 10 seconds. A general standard for the design is to obtain path reliability performance of 99.9999 percent or 31.5 seconds of potential outage per year. Path performance predictions are expected to meet minimum Bellcore Short-Haul outage reliability standards of 99.999 % or 31.5 seconds per year.

3.5.4 System Availability Calculations

The availability calculation performance criteria should be clearly defined for the microwave system. This is an end-to-end calculation defined by Bellcore, which expresses the percentage of time each system meets the performance criteria (when the end-to-end performance BER is greater than 10^{-3} for 10 consecutive and continuous SES). These system calculations are independent of the path-reliability calculation for short-term link outage events of more than 10 seconds duration discussed above.

3.5.5 Protection and Redundancy Configurations

The microwave system should be engineered to maximize protection against equipment and path failures. A monitored hot / standby configuration will provide equipment protection for links that are not configured in a loop and do not have dual links in and out of the site. The traffic will operate on the primary transceiver and switch on link to the secondary transceiver upon failure of the primary equipment. A loop-protected configuration will provide dual DS1 loop-protected links. The traffic will operate on the primary link and online backup is provided on a secondary link in case of failure to the primary link. Space diversity, frequency diversity and hybrid diversity protection configurations options are used to further protect against path failures.

3.5.6 Site Development

Microwave systems require towers or building rooftops to support the microwave system antennas and transmission lines. Communications shelters and / or buildings that house microwave communications systems need to be selected. Line-of-sight requirements, tower and structure analysis, power equipment, mechanical and floor space must also be addressed.

3.6 Microwave Radio Site Components / Equipment Configuration

The common microwave equipment components necessary at a microwave radio site are RF terminal equipment, multiplexer equipment, network alarm system, ch banks, switches, order wire, emergency power backup, antennas, transmission lines and hardware.

3.7 Summary

This chapter outlines all the related ITU-T and ITU-R objectives for digital radio/ radio relay transmission systems. From the chapter, the ITU transmission standard for microwave digital radio networking system can be summarized as under:

a. Error performance objective, BER ≤ 10E-03.

b. Worst month availability objective ≥ 99.7%

c. Annual availability objective ≥ 99.7%.

d. Total annual outage ≤ 0.3%.

    (1) Due to rainfall for frequency band:

        (a) < 7 GHz : 0 %

        (b) 7/8 ~ 11 GHz : (0.3% x 1/3) = 0.1%

        (c) 11 ~ 15 GHz : (0.3% x 2/3) = 0.2%

        (d) > 18 GHz : 0.3 %

    (2) Due to propagation impairment (e.g. multipath, equipment and other effects) for frequency band:

        (a) < 7 GHz : 0.3 %

        (b) 7/8 ~ 11 GHz : (0.3% x 2/3) = 0.2%

        (c) 11 ~ 15 GHz : (0.3% x 1/3) = 0.1%

        (d) > 18 GHz : 0%

e. Total annual outage in seconds / year ≤ 31.5

The implementation of a microwave system requires an engineering analysis to define the system requirements. The guidelines mentioned in this chapter will help to successfully install and maintain a microwave radio system.

END OF CHAPTER

CHAPTER 4
DESIGN OF AN SDH BASED MICROWAVE DIGITAL RADIO NETWORK

4.1 Introduction

This chapter is the backbone of the study. Basing on the system design requirements, the proposed tri-services microwave radio core network is designed in order to meet the microwave radio system objectives. Therefore this chapter describes the link design considerations (e.g. radio, antenna systems, bit error rate, polarization, terrain, rain effect, performance and availability objectives); transmission capacity requirements; site selections for radio stations basing on survey report; formation of possible backbone network with diagram, path profile calculation software and path profile reports of different links. The main discussion in this chapter revolves around the analytical formulations of the proposed network architecture.

4.2 Link Design Considerations

4.2.1 Radio

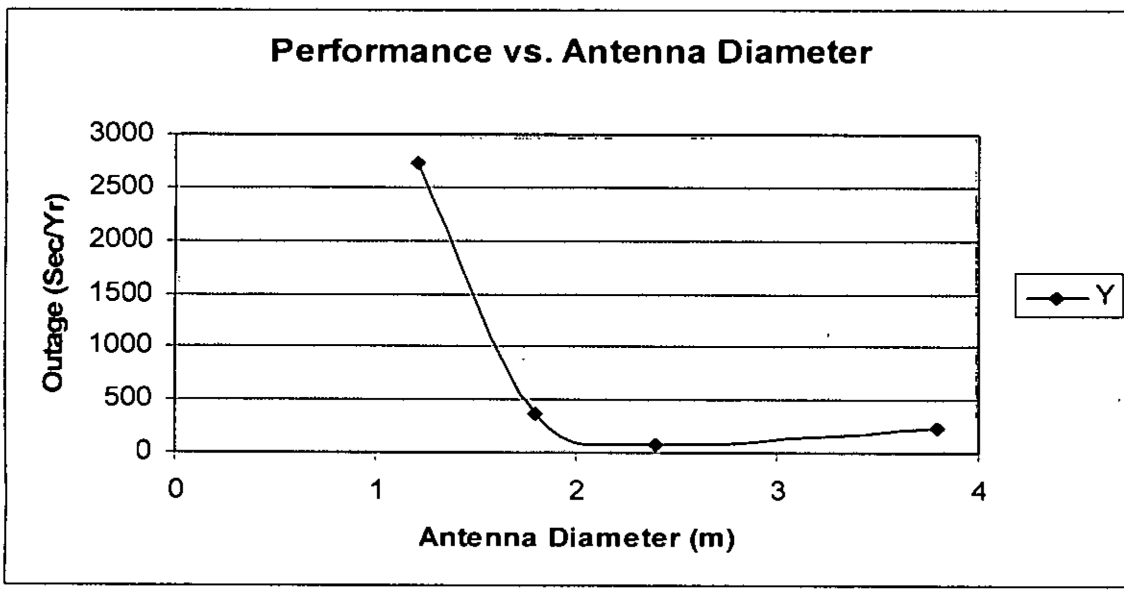
The links has been designed with the radios from Stratex Networks Inc. More precisely Altium SDH Radio (STM1 and 7/8GHz) equipment have been used for designing the network and all the major parameters of this equipment can be referred from the product specification sheet of respective model. For lateral links with lower capacity (PDH level) DXR 700 / Quantum / Spectrum II / XP 4 radio can be used. The link designing software can support both the SDH and PDH radio of the above mentioned models / series.

4.2.2 Antenna Systems-Height and Diversity with Distance

Antenna configuration for diversity varies with distance, site elevation, terrain roughness. However a typical configuration for flat terrain is mentioned below:

Ser.	Main Antenna Diameter (m)	Diversity Antenna Diameter (m)	Distance(km)
1	1.2	1.2	10 -15
2	1.8	1.2	15-20
3	1.8	1.8	20-25
4	2.4	1.8	25-30
5	2.4	2.4	30-35
6	3.0	3.0	35-40

Many a times, acceptable result is obtained with configuration of antennas having lower diameter irrespective of the recommended configuration. High diameter antennas provide high gain but cost more. Therefore decision on selection of antenna configuration should be taken considering the needed level of reliability. However a graphical representation on performance vs. antenna diameter is shown below:



On the other hand to get clear line of sight between the sites and to meet the minimum standard clearance criteria, K = 4/3 is used i.e. 60% clearance of first fresnel zone is considered. Formula used for initial prediction of antenna height is: $H_a = R_e + C$. Here H_a = height of antenna (m); R_e = fresnel ellipsoid radius (m) and C = height of interference / terrain roughness (m) - site elevation (m) above sea level (if height of interference / terrain roughness is more than the site elevation) otherwise C = 0. Antenna heights are confirmed by the path profile calculator software when the optimum link performance is obtained.

4.2.3 Bit Error Rate

For a SDH network, the bit generations at each radio side will be synchronous. In free space condition, error performance of the link shall be the same as the threshold error generation of the radio. Therefore the bit error may only occur due to unavailability factors e.g. propagation impairments, rain effects and equipment failure. To assure the performance in terms of reliability and quality of service, the path calculations are done basing on the all the equipment parameters at bit error rate of 10E-06. The threshold of the radio (minimum receive signal level, overload / maximum receive signal level) etc. has been taken at bit error rate of 10E-06. Point to note that the ITU-T error performance objective is to get BER < 10E-03.

4.2.4 Polarization

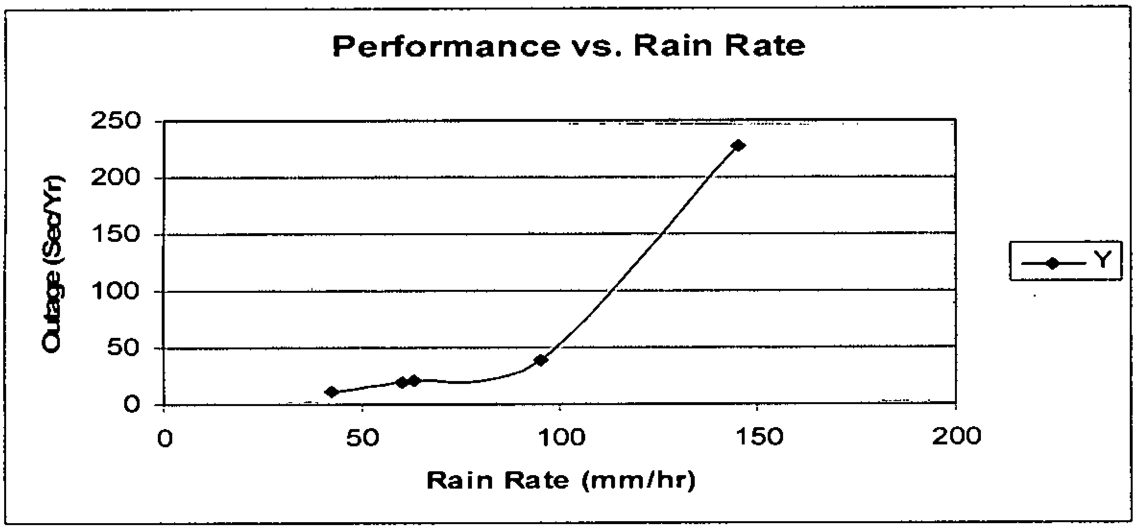
Vertical polarization is considered in the calculation since rain attenuation with horizontal polarization is higher than with vertical polarization.

4.2.5 Rain Effects

The table below describes variation of link performance in terms of potential outage (seconds/year) with respect to rain rate (mm).

Ser.	ITU Rain Region	Rain Rate (mm/hr)	Performance (Outage Sec / Yr)
1	K	42	12
2	L	60	20
3	M	63	21
4	N	95	38
5	P	145	228

The graphical representation of above table indicating the variation of link performance with respect to rain rate is shown below:



In the ITU rain map, Bangladesh falls in the region 'K' where the rain rate for 0.01% of time is 42 mm/h. But as per 'Dhaka Weather Office' the average annual rain rate for the entire country is 60 mm/h. District wise local data in relation to rain is shown below:

District	Rain Rate (mm/h)	District	Rain Rate (mm/h)	District	Rain Rate (mm/h)
Dhaka	50	Norsindhi	50	Natore	52
Tangail	42	B. Baria	60	Rajshahi	50
Mymensing	72	Hobigonj	60	Gopalgonj	56
Sirajgonj	48	Moulovibazzar	72	Noraiel	55
Bogra	50	Sylhet	88	Jessore	55
Gaibandha	50	Manikgonj	50	Khulna	80
Rangpur	80	Pabna	53	Naraongonj	50
Comilla	56	Chittagong	55	Bandorbon	80
Feni	55	Cox's Bazzar	80	Faridpur	56

Analyzing the local data, it is assumed that annual average rainfall remains 40-60 mm/h for the entire country less the northern and southern belt where this rate is between 70-90 mm/h. Considering a fair margin, we may consider ITU rain zone M for the entire country and N for links needed to be sited at the northern and southern belt for all calculations. Point to note that the rain rate for 0.01% of time at 'M' and 'N' region is 63 and 95 mm/h respectively. More over, in order to accommodate the effect of rain, the relevant ITU recommendations (Rec.530, 837 and 838) are also considered to ascertain their effect on the link.

4.2.6 Terrain Data

Digital map is available at the goggle earth and other websites which provides too approximate a site location. From the experiences, it has been noticed that location of a site shown in the goggle earth map is nearly 200 meters away from the actual site. Such error is close to unity at Dhaka and Chittagong main city but becomes too prominent at other places specially the remote sites. In such cases, use of digital elevation module (DEM) come of no use practically. Therefore we have done physical site survey in quest of accuracy. During survey, terrain roughness is considered as flat (0-6km), average (6.1-15km) and rough (15.1-43km). For better result, maximum height is considered in each category. Moreover, the links have been planned alongside the main roads / highways across which no significant physical interferences are present. GPS is used to record the height of possible sites and interference. Military map having the scale of 1 : 50,000 and 1 : 2,50,000 are also consulted for initial prediction. Since maximum values are considered therefore, actual terrain may change the availability figure shown in the sample calculations but in no case it will increase unavailability.

4.2.7 Objectives-Performance and Availability

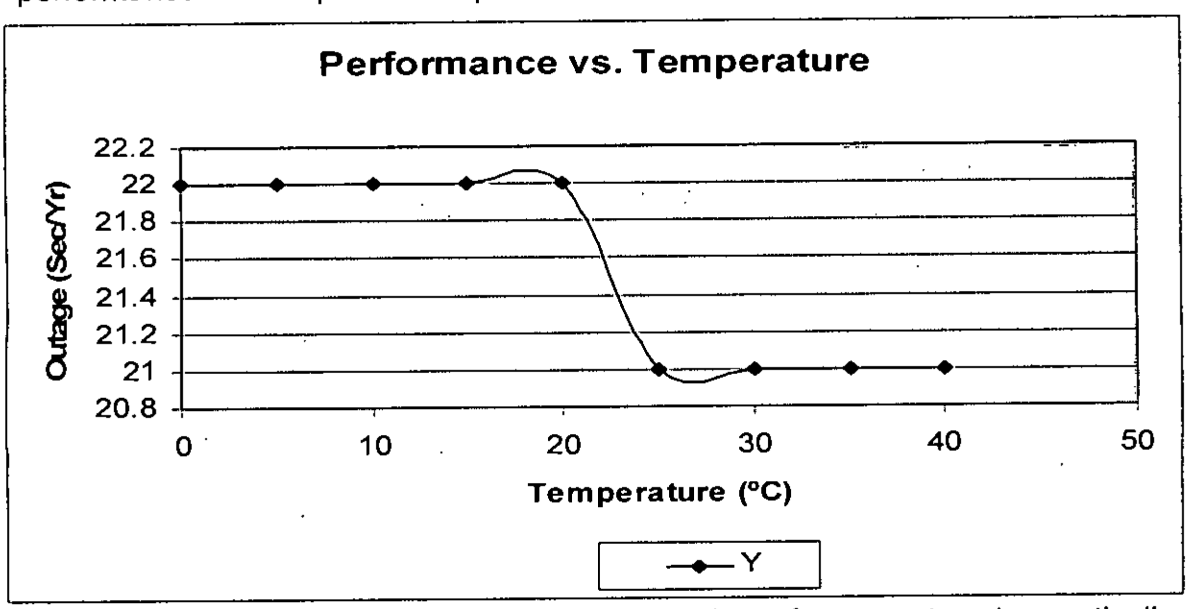
Various paths related parameters affecting the link availability, ITU-R Rec. 530-7/8 and F.557 are used. As per the recommendation, the basic availability objective considered (up to 2500km high grade systems) is ≥99.7% or unavailability objective is ≤0.3%. For error performance ITU-R Rec. 594 and 634 are used. The basic objective considered is BER ≤ 10E-03 as high grade system.

4.2.8 Temperature

The table below describes variation of link performance in terms of potential outage (seconds/year) with respect to temperature (°C):

Ser.	Temperature (°C)	Performance (Outage Seconds / Year)
1	0	22
2	5	22
3	10	22
4	15	22
5	20	22
6	25	21
7	30	21
8	35	21
9	40	21

The graphical representation of above table indicating the variation of link performance with respect to temperature is shown below:



Note: From the curve, it is observed that the effect of temperature is practically negligible.

4.3 Transmission Capacity Requirements

The requirement of the backbone capacity is one STM-1 each along the major axis of the country. The axis has been identified from strategic point of view and basing on our liberation war experiences. Those are Dhaka-Chittagong-Cox's Bazzar, Dhaka-Ghatail-Bogra-Rangpur, Dhaka-Ghatail-Mymensingh, Dhaka-Moulovibazzar-Sylhet, Dhaka-Savar-Rajshahi and Dhaka-Jessor-Khulna-Mongla. Here point to be mentioned that the capacity requirement may be increased or decreased any time by replacing radio equipment / radio transport module (RTM) cards and it does not involve much design complications.

4.4 Designing Microwave Links

4.4.1 Formation of Possible Backbone Network

Considering the probable radio sites the main transmission backbone is formed as under:

a. Dhaka-Sonargaon-Muradnagar-Comilla-Choddogram-Chagolnaiya-Mirsharai-Kumira-Chittagong-Chondonesh-Lohagara-Chiringa-Idgonj-Cox's Bazar;

b. Dhaka-Dohar-Maksudpur-Norail-Jessore-Noapara-Khulna-Mongla;

c. Dhaka-Savar-Giaor-Satyia-Atgoria-Bagha-Rajshai;

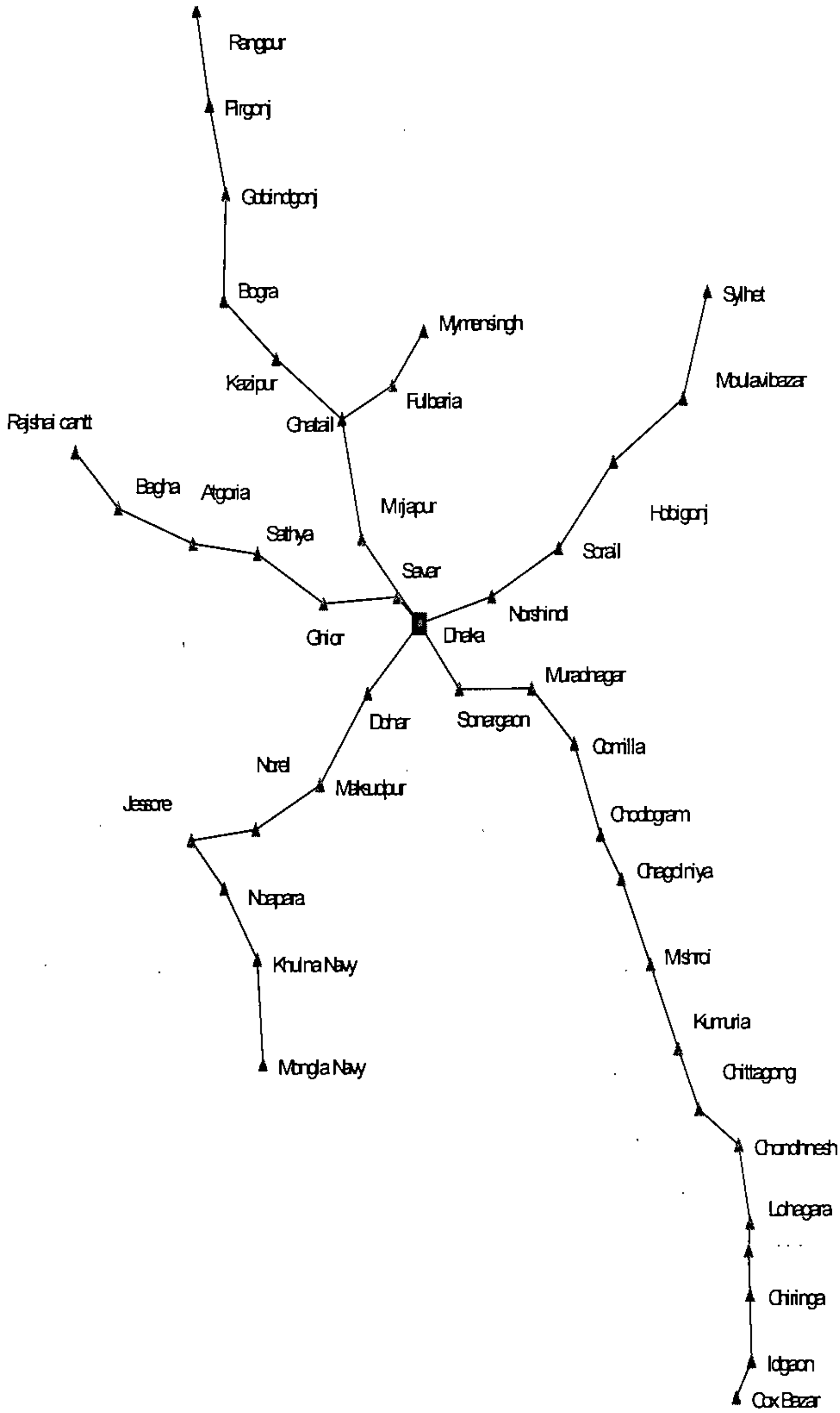
d. Dhaka-Mirzapur-Ghatail-Fulbaria-Mymensingh;

e. Dhaka-Mirzapur-Ghatail-kazipur-Bogra-Gobindogong-Pirgonj-Rangpur and

f. Dhaka-Norshindhi-Soraiel-Hobigonj-Moulovibazzar-Sylhet.

And lateral links of lower capacity (PDH level) may be formed from the backbone to connect all other military establishments. These are Dhaka-Rajendrapur, Ghatail-Rasulpur, Chittagong-Guimara-Alutila-Kaptai-Bandonbon, Alutila-Khagrachori, Kaptai Navy-Kaptai Cantoment-Rangamati and Saidpur-Rangpur-Kholahati Cantoment.

4. 4.2 Proposed Microwave Radio Core Network Diagram



4. 4.3 Description of Path Profile Calculation Software

Path profile report is prepared by a software named PathCalc(R) version 6.1. It uses two calculation modes for multipath outage (ITU-R and Vigants-Barnett) and three for rain attenuation outage (ITU-R, Crane and DMC). We have considered ITU-R calculation mode for our system for both types of outage. Received signal level and FM are expected to be within 2 dB of actual conditions. It considers only atmospheric multipath and rainfall effects on path performance since other effects has insignificant effect for frequency band less than 13 GHz.

4. 4.4 Preparation of Path Profile Report by Software

The PathCalc 6.1 is a menu given program. While operating with this program, needed dialog box appears to feed the software queries and finally it provides mainly five different reports i.e. reports on paths and sites; radio system; antenna system, loss and gain and lastly on link performance. The dialog box receives data on latitude, longitude, elevation, ITU rainfall region, gradient, climate category and temperature and provides results on azimuth and path length in the path and sites report. For radio part, the dialog box receives data on frequency band, operating frequency, radio series/model, modulation type, capacity of radio, and provides results on Tx power, Rx threshold, BER, dispersive fade margin and operating mode. Similarly the dialog box receives data on antenna system like diameter of antenna (for both primary and diversity), type and length of Tx line and antenna polarization. The loss and gain report comprises detail reports on path and equipment loss covering free space loss, atmospheric attenuation, line loss, branching loss and FM and antenna. Link performance report provides reports on Rx signal level; flat and composite FM; availability, outage in % and in seconds / year in case of worst month, 1 & 2 way transmissions due to multipath and due to annual rainfall separately and in total. Total 40 links have been designed to form the backbone network. The related path profile reports of different links are given at appendix A.

END OF CHAPTER

CHAPTER 5
PERFORMANCE ANALYSIS OF THE DESIGNED NETWORK

5.1 Introduction

This chapter describes the evaluation process of the designed network. Basing on the path profile reports and ITU transmission standard, required software has been developed to assess the performance of every individual link. The main discussion in this chapter involves the analytical comparisons of performance of the proposed network with the ITU published transmission standard to ascertain the correctness of the designed network.

5.2 Considerations for Performance Analysis of the Designed Network

5.2.1 ITU Transmission Standard

Before final approval of ITU-R Recs. G826 and G.827, following ITU transmission standard for microwave digital radio networking system are applicable:

a. Error performance objective, BER ≤ 10E-03.
b. Annual availability objective ≥ 99.7%.
c. Total annual outage ≤ 0.3%.
d. Total annual outage in seconds / year ≤ 31.5
e. Worst month availability = 99.7%

5.2.2 General Standard of Link or Path Reliability

A general standard for the design is to obtain path reliability performance of 99.9999 % or 31.5 seconds of potential outage per year. This is the minimum Bellcore short-haul path performance reliability and outage standards. Almost all telecom companies follow this general standard while designing microwave link, evaluating link performance and determining link reliability.

5.2.3 Summary of Path Profile Report of the Designed Network

MICROWAVE PATH PROFILE REPORT – DATA SHEET

Common Design Feature:

1. Link Features - Capacity : STM-1; Freq Band : 7~8GHz;Polarization : Vertical & Protection System : (1+1) Space Diversity.
2. Radio Features - Series : ALTIUM SDH; Modulation :128QAM;Tx Power : 24dBm; Rx Threshold : -68 dBm; BER : 10E-06 & DFM : 43 dB.
3. ITU-T Objectives - Error Perf. Obj. ≤ 10E-03 : Availability Obj. ≥ 99.7%.

Site A	Site B	Path Length (km)	Both Ant. Dia (m) at Each Site	BER	Rx Signal (dBm)	Net Path Loss (dB)	Flat Fade Margin (dB)	Worst Month Availability (%)-Multipath	Annual Availability (%)-Rain	Annual Availability (%)-Total	Annual Outage (%)-Total	Seconds / Year
Dhaka-Commila-Chittagonj-Cox's Bazzar (13 Links)												
Dhaka	Sonargaon	30.95	2.4	10E-6	-34.5	58.5	33.5	99.999961	99.999971	99.999932	0.000068	21
Sonargaon	Muradnagar	37.78	3	10E-6	-31.6	55.6	36.4	99.999982	99.999974	99.999961	0.000039	12
Muradnagar	Comilla	29.38	2.4	10E-6	-30.3	54.3	37.7	99.999991	99.999987	99.99998	0.00002	6
Comilla	Chodogram	34.16	3	10E-6	-28.2	52.2	39.8	99.999989	99.999987	99.999978	0.000022	7
Chodogram	Chagolniya	18.57	1.8+1.2	10E-6	-31.8	55.8	36.2	99.999998	99.999997	99.999995	0.000005	2
Chagolniya	Mishroi	33.27	2.4	10E-6	-33.4	57.4	34.6	99.999978	99.999973	99.999956	0.000044	14
Mishroi	Kumuria	32.19	2.4	10E-6	-33.4	55.3	36.7	99.999992	99.999944	99.999939	0.000061	19
Kumuria	Chittagong	23.68	2.4	10E-6	-30.9	54.9	37.1	99.999995	99.999965	99.999962	0.000038	12
Chittagong	Chondhnesh	24.41	2.4	10E-6	-30.1	54.1	37.9	99.999997	99.999967	99.999965	0.000035	11
Chondhnesh	Lohagara	27.64	2.4	10E-6	-30.2	54.2	37.8	99.999995	99.99996	99.999956	0.000044	14
Lohagara	Chiringa	24.24	2.4+1.8	10E-6	-28.6	52.6	39.4	99.999997	99.999973	99.999971	0.000029	9
Chiringa	Idgaon	22.43	2.4+1.8	10E-6	-28	52	40	99.999998	99.999978	99.999977	0.000023	7
Idgaon	Cox Bazar	14.34	1.2	10E-6	-36	60	32	99.999999	99.99997	99.99997	0.00003	10
Dhaka-Jessore-Khulna-Mongla (07 Links)												
Dhaka	Dohar	36.65	3	10E-6	-30.9	54.9	37.1	99.999982	99.999978	99.999964	0.000036	11
Dohar	Maksudpur	39.55	3	10E-6	-31.7	55.7	36.3	99.999979	99.999971	99.999956	0.000044	14
Maksudpur	Noraiel	37.3	3	10E-6	-30.1	54.1	37.9	99.999982	99.99998	99.999965	0.000035	11
Noraiel	Jessore	33.96	2.4	10E-6	-35	59	33	99.999961	99.999963	99.999934	0.000066	21
Jessore	Noapara	23.68	2.4	10E-6	-30.9	54.9	37.1	99.999998	99.999965	99.999964	0.000036	11
Noapara	Khulna	30.25	2.4	10E-6	-30.4	54.9	37.6	99.999985	99.999954	99.999937	0.000063	20

Site A	Site B	Path Length (km)	Both Ant. Dia (m) at Each Site	BER	Rx Signal (dBm)	Net Path Loss (dB)	Flat Fade Margin (dB)	Worst Month Availability (%)-Multipath	Annual Availability (%)-Rain	Annual Availability (%)-Total	Annual Outage (%)-Total	Seconds / Year
Khulna	Mongla	36.65	3	10E-6	-30	54	38	99.999983	99.999945	99.999931	0.000069	22

Dhaka-Savar-Rajshai (06 Links)

Dhaka	Savar	14.71	1.2	10E-6	-36.6	60.6	31.4	99.999997	99.999996	99.999994	0.000006	2
Savar	Ghior	38.96	3	10E-6	-30.6	54.6	37.4	99.999979	99.999976	99.99996	0.00004	12
Ghior	Sathya	38.91	3	10E-6	-30.6	54.6	37.4	99.99998	99.999976	99.999961	0.000039	12
Sathya	Atgoria	33.8	3	10E-6	-31.1	55.1	36.9	99.999984	99.999981	99.999968	0.000032	10
Atgoria	Bagha	40.71	3	10E-6	-32.4	56.4	35.6	99.999964	99.999967	99.99994	0.00006	19
Bagha	Rajshahi	30.23	2.4	10E-6	-30.4	54.4	37.6	99.999989	99.999986	99.999977	0.000023	7

Dhaka-Ghatail-Bogra-Rangpur (07 Links)

Dhaka	Mirjapur	41.79	3	10E-6	-31.6	55.6	36.4	99.999974	99.999969	99.99995	0.00005	16
Mirjapur	Ghatail	42.77	3	10E-6	-33.1	57.1	34.9	99.999934	99.999996	99.999911	0.000089	28
Ghatail	Kazipur	40.45	3	10E-6	-32.6	56.6	35.4	99.999967	99.999966	99.999942	0.000058	18
Kazipur	Bogra	33.96	3	10E-6	-29	53	39	99.99999	99.999986	99.999978	0.000022	7
Bogra	Gobindgonj	36.79	3	10E-6	-30	54	38	99.999984	99.99998	99.999968	0.000032	10
Gobindgonj	Pirgonj	32.04	3	10E-6	-28.1	52.1	39.9	99.999992	99.999962	99.999956	0.000044	14
Pirgonj	Rangpur	32.45	3	10E-6	-28.2	52.2	39.8	99.999992	99.999961	99.999955	0.000045	14

Ghatail-Mymensingh (02 Links)

Ghatail	Fulbaria	28.86	2.4	10E-6	-31	55	37	99.99999	99.999953	99.999946	0.000054	17
Fulbaria	Mymensingh	25.06	2.4	10E-6	-29.7	53.7	38.3	99.999995	99.999967	99.999963	0.000037	12

Dhaka-Moulavibazzar-Sylhet (05 Links)

Dhaka	Norshindi	39.51	3	10E-6	-31.7	55.7	36.3	99.999977	99.999971	99.999955	0.000045	14
Norshindi	Sorail	39.66	3	10E-6	-31.7	55.7	36.3	99.99998	99.999971	99.999957	0.000043	13
Sorail	Hobigonj	40.84	3	10E-6	-32.4	56.4	35.6	99.999961	99.999966	99.999938	0.000062	20
Hobigonj	Moulavibazar	42.64	3	10E-6	-33.1	57.1	34.9	99.999937	99.99996	99.999913	0.000087	27
Moulavibazar	Sylhet	39.06	3	10E-6	-31.6	55.6	36.4	99.999982	99.999929	99.999917	0.000083	26

5.3 Evaluation Tool / Developed Software

Basing on the ITU transmission standard, an evaluation tool named 'Microwave Link Evaluation Software' has been developed to assess the performance of the designed links. The developed software is general in nature which can be used for any microwave link / network designed with any related equipment configuration produced by any microwave equipment production company.

5.3.1 Objectives of the Developed Software

Main objective of this software is to evaluate the performance of every individual microwave link designed to form a complete network keeping ITU transmission standards in consideration and to identify whether microwave radio system provides dependable and standard performance or not. Other objectives are:

a. To find out technical weaknesses in particular field of the transmission equipment to reach ITU transmission standard so that the transmission companies can address the limitations and promote their products to achieve optimum level of reliability and quality of services.
b. To filter non-quality transmission equipment before the physical installation and infrastructure setup.
c. To assist reaching the best decision by selecting the best transmission equipment for network establishment.

5.3.2 Software Design Consideration

The soft ware needs to deal with few fields on transmission characteristics and path which indicates and regulates the performance of transmission equipment and link. These fields are net path loss and FM to predict the link viability; BER to ascertain the error performance; annual link availability, annual outage, and potential outage to assess the total annual link availability and path reliability to determine the reliability standard. Besides, in order to process decisions on performance, the ITU transmission standard on above mentioned fields needs to considered as reference, with which the data on the same field from the path profile report of the designed link has to be compared. Therefore two sets of input data are required i.e. static / fixed value or input which is the ITU transmission standard and variable inputs which are the pertinent data from the path profile report of the designed link. The desired output has been generally categorized and designed either reliable (R) or unreliable (U) in order to reach to a clean and precise decision. The program makes the decision simply by comparison process. To make the software a general or universal one, preparation of databases on both the inputs has been intentionally avoided. Otherwise preparation of input database shall make the program special to a particular equipment configuration which shall lead the program to the limitation of uniqueness and to lose the characteristics of generalness.

5.3.3 Necessary Fields and Decision Processing

Necessary fields and the decision making process is tabulated below. The category of performance is expressed as R (reliable) if the output / result is better than or equal to ITU transmission standard and otherwise U (unreliable).

Performance Analysis for Assessment

Error Performance Analysis

ITU Standard	**Link Performance**	**Processing ($P_{link} < P_{ITU}$)**	**Result / Decision** (Reliable / Unreliable)
BER < 10^{-3}	BER = 10^{-6}		R / U

Availability Analysis

Field	**ITU Standard (P_{ITU})**	**Link Perf. (P_{Link})**	**Processing ($P_{Link} \geq P_{ITU}$)**	**Result / Decision** (Reliable/Unreliable)
Worst Month Availability (%)	99.7%			R / U
Annual Availability (%) Considering Rain Effect only				
(1) < 7 GHz	(100% -0%)			R / U

(2) 7/8 ~ 11 GHz	(100% - 0.1%)			R / U
(3) 11 ~ 15 GHz	(100% - 0.2%)			R / U
(4) > 18 GHz	(100% - 0.3%)			R / U
Annual Availability (%) considering Multipath & Equipment Failure only				
(1) < 7 GHz	(100% - 0.3%)			R / U
(2) 7/8 ~ 11 GHz	(100% - 0.2%)			R / U
(3) 11~15 GHz	(100% - 0.1%)			R / U
(4) > 18 GHz	(100% - 0%)			R / U
Total Annual Outage (%)	0.3%		$P_{Link} \leq P_{ITU}$	R / U
Total Annual Availability (%)	(100% - 0.3%)			R / U

Path Reliability Analysis

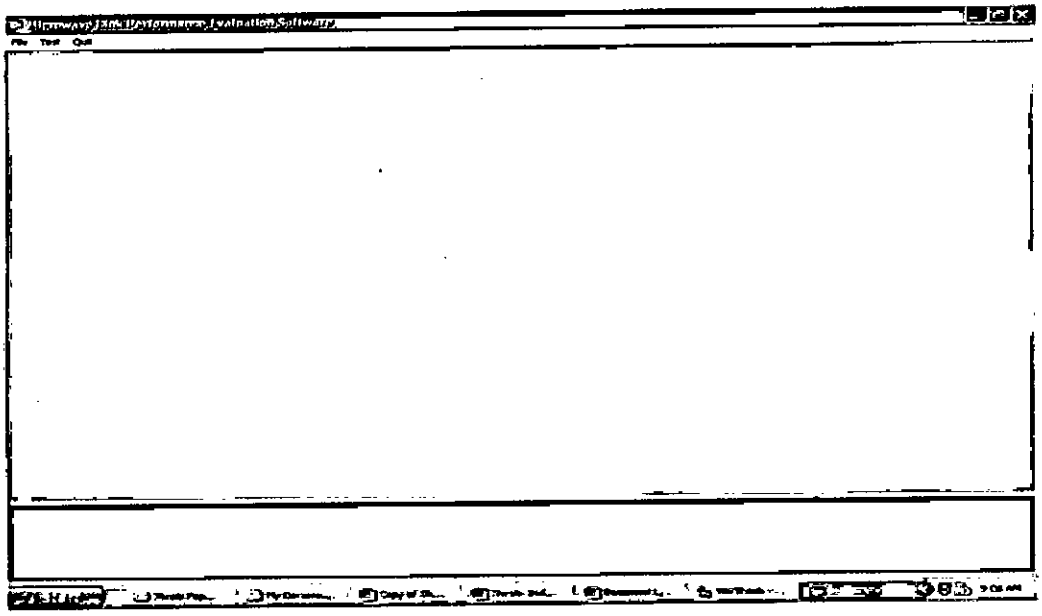
Field	**ITU Standard (P_{ITU})**	**Link Perf. (P_{Link})**	**Processing**	**Result / Decision** (Reliable/Unreliable)
Path Reliability Performance %	99.9999%		$P_{link} \geq P_{ITU}$	Reliable / Unreliable.
Potential Outage (Second/Year)	31.5			R / U

Signal Power Analysis for Link Viability Prediction

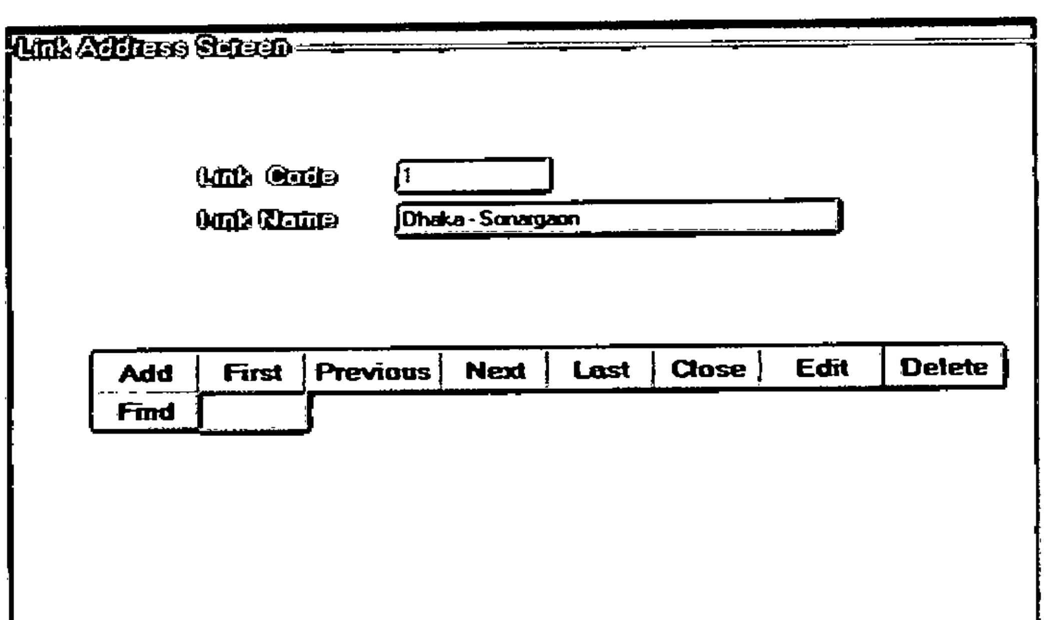
Field	**P_{Tx} (dBm)**	**P_{Rx} (dBm)**	**Processing**	**Result/Decision (Prediction)**
Net Power Loss (NPL in dB)			NPL (dB) = P_{Tx} (dB_m) – P_{Rx} (dB_m)	Viable / Needs Regulation / Unviable
Fade Margin (FM in dB)			FM(dB) = P_{Rx} (dB_m) – P_{TH} (dB_m)	Viable / Needs Regulation / Unviable

5.3.4 Detail Description of the Developed Program

This software is developed in Visual Basic 6. It has four interfaces to handle the entire program. Details are as shown below:

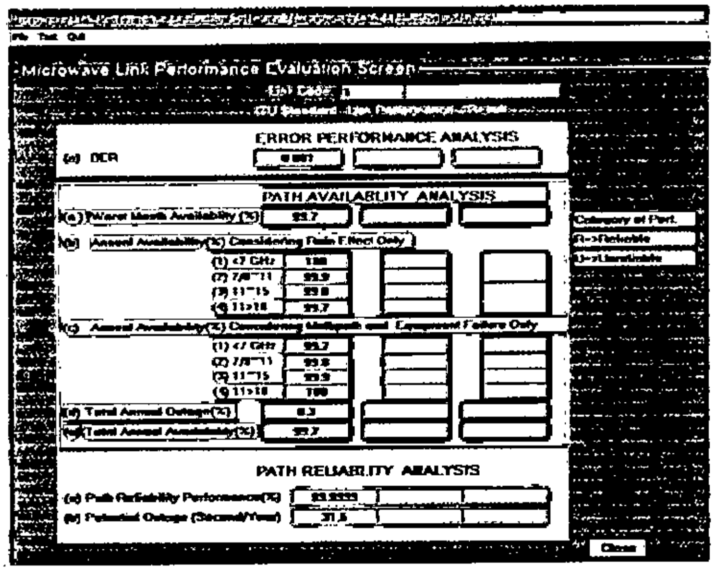


Opening screen is the main interface for handling the program to go and operate the other screen / form.

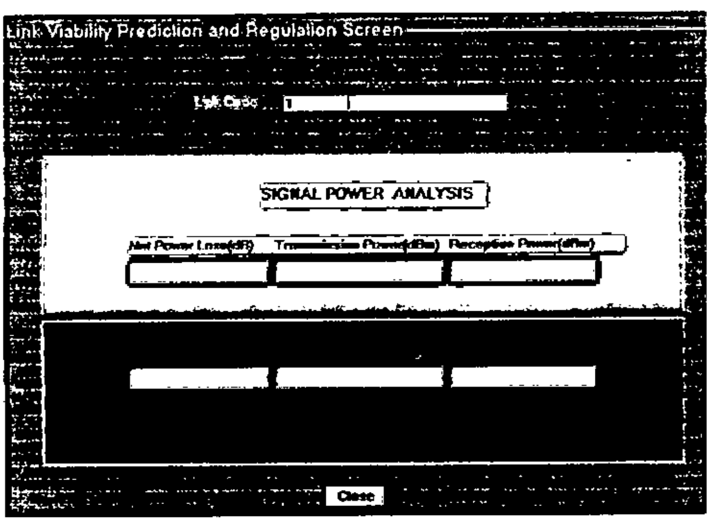


Link address screen is the interface that contains the related link information. By this form we can store link information to database (SQL-7).

Link performance evaluation screen is the interface that processes decision by comparing two different inputs i.e. static and variable inputs. Static input is the ITU Tx standard which is fixed and maintained in a table. Variable inputs are related data which are fed from path profile report of the designed link. Output of the comparison process is the decision on the level of performance. Category of performance is expressed as R (reliable) if the result is better than or equal to ITU Tx standard and otherwise U (unreliable).



Link viability prediction screen is the interface that receives three variable inputs (Tx, Rx and threshold power) to provide two outputs (net power loss and FM) which help to predict the link viability before actual deployment of the equipment. Point to note here that the input data from the equipment specification will indicate the allowable output limit. Therefore during the installation, it will also help the installation engineer to regulate the installation work to reach up to the allowable output limit. After the installation work, prediction for link viability can be done for that particular area for a particular equipment configuration taking the regulated output as reference.



5.4 Evaluation Report of the Designed Links

Category of Performance: Reliable(R) if result is better than or equal to ITU Obj. and Unreliable (U) otherwise.

Link	Error Performance Analysis		Result (R / U)	Availability Analysis			Outage Analysis					
	ITU Std (BER)	Link Perf.		ITU Avail. Obj. (%)	Annual Link Availability (%)	Result (R / U)	ITU Outage Obj. (%)	Annual Outage (%)	Result (R / U)	Potential Outage: Gen Std Sec/Yr	Potential Outage: Link Perf. Sec/Yr	Result (R / U)
Dhaka-Commila-Chittagonj-Cox's Bazzar (13 Links)												
Dhaka-Sonargaon	<10E-3	10E-6	R	99.7	99.999932	R	0.3	0.000068	R	31.5	21	R
Sonargaon-Muradnagar	<10E-3	10E-6	R	99.7	99.999961	R	0.3	0.000039	R	31.5	12	R
Muradnagar-Comilla	<10E-3	10E-6	R	99.7	99.99998	R	0.3	0.00002	R	31.5	6	R
Comilla-Chodogram	<10E-3	10E-6	R	99.7	99.999978	R	0.3	0.000022	R	31.5	7	R
Chodogram-Chagolniya	<10E-3	10E-6	R	99.7	99.999995	R	0.3	0.000005	R	31.5	2	R
Chagolniya-Mishroi	<10E-3	10E-6	R	99.7	99.999956	R	0.3	0.000044	R	31.5	14	R
Mishroi-Kumuria	<10E-3	10E-6	R	99.7	99.999939	R	0.3	0.000061	R	31.5	19	R
Kumuria-Chittagong	<10E-3	10E-6	R	99.7	99.999962	R	0.3	0.000038	R	31.5	12	R
Chittagong-Chondhnesh	<10E-3	10E-6	R	99.7	99.999965	R	0.3	0.000035	R	31.5	11	R
Chondhnesh-Lohagara	<10E-3	10E-6	R	99.7	99.999956	R	0.3	0.000044	R	31.5	14	R
Lohagara-Chiringa	<10E-3	10E-6	R	99.7	99.999971	R	0.3	0.000029	R	31.5	9	R
Chiringa-Idgaon	<10E-3	10E-6	R	99.7	99.999977	R	0.3	0.000023	R	31.5	7	R
Idgaon-Cox Bazar	<10E-3	10E-6	R	99.7	99.99997	R	0.3	0.00003	R	31.5	10	R
Dhaka-Jessore-Khulna-Mongla (07 Links)												
Dhaka-Dohar	<10E-3	10E-6	R	99.7	99.999964	R	0.3	0.000036	R	31.5	11	R
Dohar-Maksudpur	<10E-3	10E-6	R	99.7	99.999956	R	0.3	0.000044	R	31.5	14	R
Maksudpur-Noraiel	<10E-3	10E-6	R	99.7	99.999965	R	0.3	0.000035	R	31.5	11	R
Noraiel-Jessore	<10E-3	10E-6	R	99.7	99.999934	R	0.3	0.000066	R	31.5	21	R
Jessore-Noapara	<10E-3	10E-6	R	99.7	99.999964	R	0.3	0.000036	R	31.5	11	R
Noapara-Khulna	<10E-3	10E-6	R	99.7	99.999937	R	0.3	0.000063	R	31.5	20	R
Khulna-Mongla	<10E-3	10E-6	R	99.7	99.999931	R	0.3	0.000069	R	31.5	22	R

Link	Error Performance Analysis		Result (R / U)	Availability Analysis			Outage Analysis					
	ITU Std (BER)	Link Perf.		ITU Avail. Obj. (%)	Annual Link Availability (%)	Result (R / U)	ITU Outage Obj. (%)	Annual Outage (%)	Result (R / U)	Potential Outage		Result (R / U)
										Gen Std Sec/Yr	Link Perf. Sec/Yr	
Dhaka-Savar-Rajshai (06 Links)												
Dhaka-Savar	<10E-3	10E-6	R	99.7	99.999994	R	0.3	0.000006	R	31.5	2	R
Savar-Ghior	<10E-3	10E-6	R	99.7	99.99996	R	0.3	0.00004	R	31.5	12	R
Ghior-Sathya	<10E-3	10E-6	R	99.7	99.999961	R	0.3	0.000039	R	31.5	12	R
Sathya-Atgoria	<10E-3	10E-6	R	99.7	99.999968	R	0.3	0.000032	R	31.5	10	R
Atgoria-Bagha	<10E-3	10E-6	R	99.7	99.99994	R	0.3	0.00006	R	31.5	19	R
Bagha-Rajshahi	<10E-3	10E-6	R	99.7	99.999977	R	0.3	0.000023	R	31.5	7	R
Dhaka-Ghatail-Bogra-Rangpur (07 Links)												
Dhaka-Mirjapur	<10E-3	10E-6	R	99.7	99.99995	R	0.3	0.00005	R	31.5	16	R
Mirjapur-Ghatail	<10E-3	10E-6	R	99.7	99.999911	R	0.3	0.000089	R	31.5	28	R
Ghatail-Kazipur	<10E-3	10E-6	R	99.7	99.999942	R	0.3	0.000058	R	31.5	18	R
Kazipur-Bogra	<10E-3	10E-6	R	99.7	99.999978	R	0.3	0.000022	R	31.5	7	R
Bogra-Gobindogonj	<10E-3	10E-6	R	99.7	99.999968	R	0.3	0.000032	R	31.5	10	R
Gobindgonj-Pirgonj	<10E-3	10E-6	R	99.7	99.999956	R	0.3	0.000044	R	31.5	14	R
Pirgonj-Rangpur	<10E-3	10E-6	R	99.7	99.999955	R	0.3	0.000045	R	31.5	14	R
Ghatail-Mymensingh (02 Links)												
Ghatail-Fulbaria	<10E-3	10E-6	R	99.7	99.999946	R	0.3	0.000054	R	31.5	17	R
Fulbaria-Mymonshing	<10E-3	10E-6	R	99.7	99.999963	R	0.3	0.000037	R	31.5	12	R
Dhaka-Moulavibazzar-Sylhet (05 Links)												
Dhaka-Norshindi	<10E-3	10E-6	R	99.7	99.999955	R	0.3	0.000045	R	31.5	14	R
Norshindi-Sorail	<10E-3	10E-6	R	99.7	99.999957	R	0.3	0.000043	R	31.5	13	R
Sorail-Hobigonj	<10E-3	10E-6	R	99.7	99.999938	R	0.3	0.000062	R	31.5	20	R
Hobigonj-Moulovibazar	<10E-3	10E-6	R	99.7	99.999913	R	0.3	0.000087	R	31.5	27	R
Moulavibazar-Sylhet	<10E-3	10E-6	R	99.7	99.999917	R	0.3	0.000083	R	31.5	26	R

5.5 Results and Findings / Discussions

Considering ITU transmission standard, general standard for path reliability and summary of the path profile report, the link performance and the link reliability can easily be evaluated and determined. The specific findings of above mentioned evaluation are as follows:

a. The network designed is as per the ITU transmission standard which implicitly assures the link / path reliability.

b. In addition, the designed network also meets the general standard for link / path reliability or Bellcore short-haul path performance reliability and outage standards which almost all the telecommunication companies follow while designing the microwave link, evaluating the link performance and determining the link reliability.

c. The evaluation report produced by the developed software 'Microwave Link Evaluation Software' also confirms the correctness of the designed link / network.

5.6 Summary

Basing on the path profile reports and ITU transmission standard, 'Microwave Link Evaluation Software' has been developed to assess the performance of the designed links. The developed programming is general in nature which can be used for any microwave link / network designed with any related equipment configuration. With the help of this software, it is found that the proposed microwave core radio network is designed as per the ITU transmission standard and general standard for path / link reliability. Therefore the reliability and quality of services of the designed network is optimum and assured by the ITU transmission guidelines.

END OF CHAPTER

CHAPTER 6

EVOLUTION OF SDH TECHNOLOGY AND ITS COMPATIBILITY / MIGRATION TO NEXT GENERATION NETWORK

6.1 Introduction

The term communication and transmission are often interchangeably used. SDH means Synchronous Digital Hierarchy which is recommended as the standard for digital multiplexing hierarchy by CCITT. It is equally applicable for communication and transmission i.e. for both access and transmission network. In this chapter we shall discuss about the evolution process and reasons to select SDH technology for transmission network designing as well as its compatibility and migration possibility to Next Generation Network (NGN).

6.2 Evolution from Analog to Digital System

6.2.1 Analog System

For around two decades, analog systems prevailed and ruled the world. But inherently the analog system had following limitations:

a. Being a continuous signal, the in-built noise signal can not be removed by filtering.

b. For high capacity communication, it needs huge bandwidth.

c. Design and maintenance of equipment becomes complex and costly.

Being unable to remove the in-built noise of the analog signal by filtering and being unable to increase the volume of channels up to a certain level without sacrificing cost and performance in order to meet the requirements of the increased tele density, the need of new technology becomes inevitable. And that is digital system.

6.2.2 Digital System

In digital system the original analog signal is cut into pieces to remove its in-built noisy and bulky nature for better control. But the precondition is that when it will reach to human ear it should be reproduced as its original form. The era of digital system starts when Mr. A.H. Reaves (USA) in 1938 developed Pulse Code Modulation (PCM) system to transmit the spoken word in digital. PCM system use TDM (Time Division Multiplexing) technique to provide a huge number of circuits on the same transmission medium. PCM follows four steps i.e. filtering, sampling, quantizing, encoding and line coding. The analog speech signal is sampled by sampling theorem. For calculation voice frequency range is assumed to be in the range of 0-4 KHz. Sampling theorem says $Fs \geq 2f_H$, where f_H is the highest frequency of the signal and Fs is the sampling frequency. Here Fs = 2 X 4 = 8 KHz. Therefore the sampler produces 8000 samples per second.

Time period of sampling is, Ts =1/8000=125 μs. This is known as TDM frame duration. If there is only one voice channel, then it will be sampled after 125 μs. But as per A-Law of quantization 30 voice channels should be sampled together and another two channels are needed for synchronization and signaling. So total 32 channels need to be sampled in 125 μs and each channel is given a time slot (TS) of 125/32=3.9 μs. Hence there are 32 TS for 32 channels i.e. TS 0 is for synchronization, TS 16 is for signaling and rest for voice signal. The sampling signal is passed through quantizer and encoder to make it a digital signal. The output of encoder is binary signal i.e. this signal has two states '0' and '1' called bit. Each signal is expressed by 8 bits or 1 byte. Each PCM takes 30 analog voice channels of 300-3400 Hz signal as input to make digital output by producing series of zeroes and ones. Each sample of voice signal is expressed by 8 bits and thus each channel capacity becomes 8000 x 8 = 64 kbps. Therefore one PCM frame can carry = 64 kbps x 32 = 2.048 Mbps. This PCM (known as E1) is the most used commercial term for interconnection process. The digital multiplexing or grouping is done by this TDM technique.

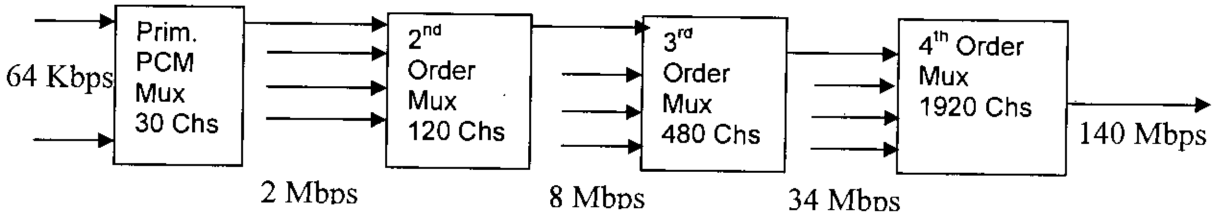


Figure: Multiplexer

On the other end, again this bundle needs to open up to channel level by de-multiplexing process. This process comes down to 300 to 3400 Hz voice signal level to reach this to human ear. This kind of multiplexing/de-multiplexing hierarchical process is called Plesiochronous Digital Hierarchy (PDH) system. This digital system also could not meet the growing demand of telecommunication because:

a. It is not a flexible network i.e. one network is not synchronized with another network.

b. Drop and insert of channels does not make for every flexible connection pattern or rapid provisioning of services, while the multiplexer mountains required extremely expensive.

c. Every hierarchy has to maintain for a single channel adding/dropping.

d. PDH frame structure has insufficient provision for carrying network management information.

6.2.3 Evolution of Synchronous Digital Hierarchy (SDH) System

Limitations of PDH systems are not critical in a network dominated by voice traffic only, but as more sophisticated services become popular, PDH can no longer cope with it. So, the mankind has to think about another digital communication system. That is SDH system which allows different types of traffic such as voice, video, multimedia and packet based data as IP. The prime advantages of SDH network are as follows:

a. Interfaces can be made with all existing PDH and ATM networks.

b. Easy upgrade to higher rates.

c. Inter manufacturer connection is easier.

d. High level of network protection and easy network management.

6.2.3.1 Synchronous Transport Module

Information is packaged into a Synchronous Transport Module (STM) in order that it can be transported and managed across SDH network. SDH system contains the following elements:

a. Container: Basic element of STM. It consists of unit PDH signal; it is of different type according to PDH signal rate.

   (1) Container C11 & 12 contains 1544 & 2948 Kbps

   (2) Container C2 & C3 contains 6312 & 34368 / 44736 Kbps

   (3) Container C4 contains 139368 Kbps

b. Virtual Container (VC): It is the package of the container and its associated path overhead.

c. Nesting: A virtual container can contain other virtual containers, known referred to as nesting. Example- a VC-4 can be packaged with 63 VC-12s.

d. STM: To actually carry VCs over the network several of them are placed in a STM. The STM frame forms as:

Section overhead area	Payload area

   (1) Payload - VCs are placed in the payload area of STM.

   (2) Section Overhead (SOM) - These information bytes are added to STM frame providing a communication ch between adjacent nodes enabling control of Tx over the link.

   (3) Pointer - VC is PDH traffic. Whenever a pointer is added to a VC, it becomes SDH traffic called Tributary Unit (TU). Pointer denotes the actual location of VC within the pay load of STM that helps to extract the original signal from STM.

6.2.3.2 STM-1 Base Frame

1..............................9 10..............................270 (bytes)

1 (byte) RSOH	P	
AU pointer	O	C4
MSOH	H	

SOM PAYLOAD

SOH (Section Overhead) = MSOH (Multiplexing Section Overhead) + RSOH (Regeneration Section Overhead) and POH = Path Overhead.

Total Length = 2430 bytes, Duration = 125 μs, Rate of STM1=2430x8x8000 = 155.520 Mbps, Payload =2340 bytes i.e. = 149.760 Mbps and Overhead=90 bytes, i.e. = 5.76 Mbps.

So one STM-1 contains around 155 millions of bits signal or one STM-1 can contain one C4 i.e. one 144 Mbps signal or it can bring 3 TU-12x7 TUG 2 x 3 AU-3 = 63 E1s. The huge overhead bytes show how much precision have been taken in SDH system. Through higher order multiplexing the capacity can be increased to STM-64 (10 Gbps) or above.

6.2.3.3 Multiplexing structure

The complete international SDH multiplexing structure is shown below. It provides access for PDH signals at the European rates of 2, 34 and 140 Mbps and the North American Rates of 1.5, 6.3 and 45 Mbps. Note that the European rate of 8Mbit/s is not supported. There are a number of multiplexing routes available to arrive at a STM-1 frame to cater for the historical PDH hierarchies and formats.

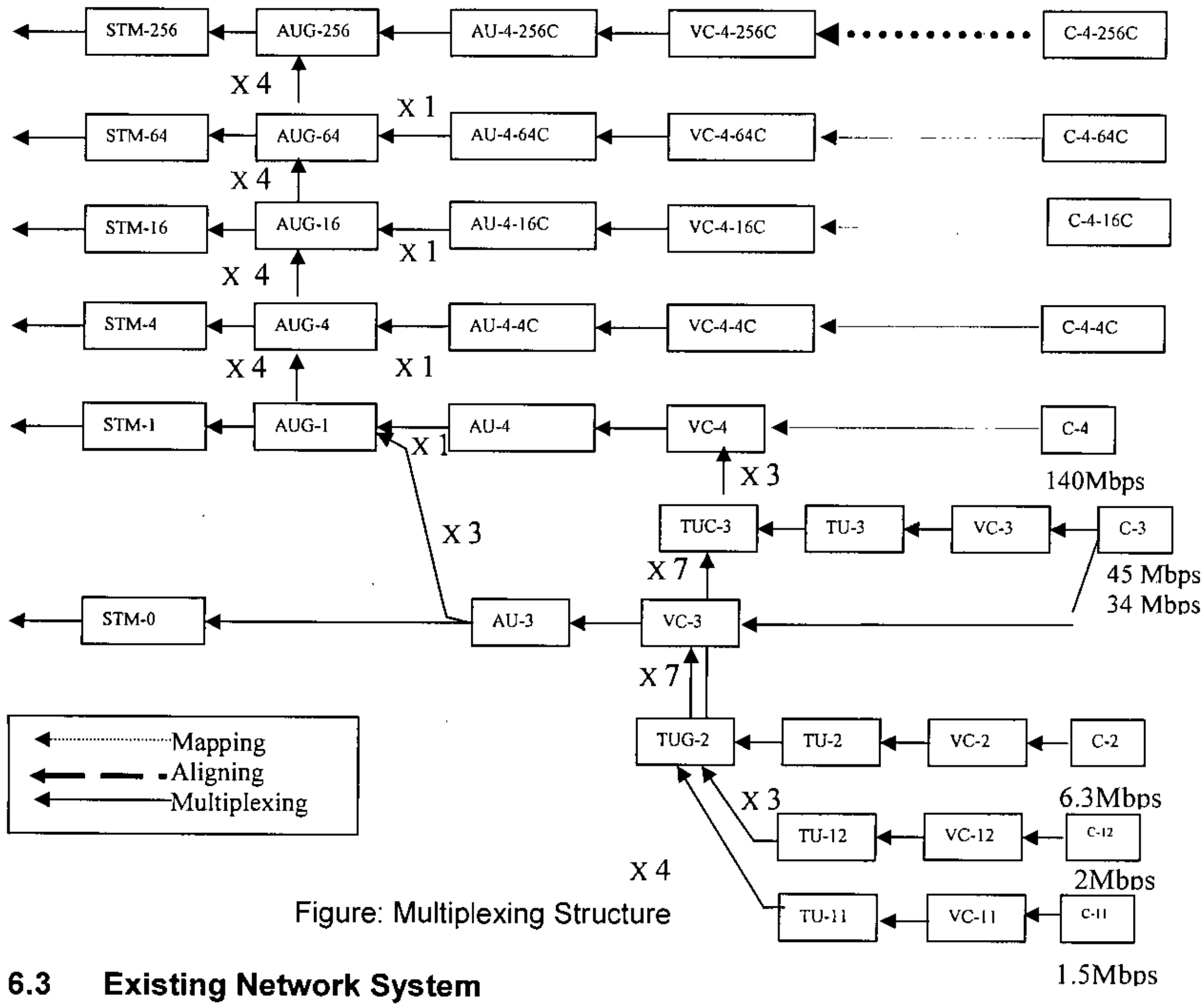


Figure: Multiplexing Structure

6.3 Existing Network System

The concept of a network emerges when several sources and links of information are to be interconnected. Existing network system has two distinct segments i.e. access network and transmission network.

6.3.1 Access Network

Broadly there are two main forms of the existing access network system i.e. telephone network and data network.

6.3.1.1 Telephone Network

The telephone network comprises Tx chs which are assigned to users either on a permanent base or dynamically. In the later case, switching is necessary. The switching operation interconnects two users when they request for interconnection. Switching is performed at the network exchanges. The telephone network provides analog voice service. When digitized the same becomes 64 kbps digital signal which forms a ch at the switch end for onward tx to a long distance networked exchange / switch out side the access network through digital radio. Besides, the telephone network resources can be also used for transporting digital information as well.

6.3.1.2 Data Network

Data network works on the principles of dynamic channel allocation. Switching operation interconnects two users when they request for interconnection. Switching is performed at the network server / gateway. Data network provides data services by digital signal at the device end. The bit rate of such a signal is dynamically controlled at the server / gateway end for onward tx to either long distance networked server / gateway out side the access network or to another subscriber / server at short distance with in the access network. However at both the cases, the digital signal at the server end is of universal standard i.e. 56 / 64 kpbs (or its index).

6.3.2 Transmission Network

Transmission network connects the access networks or end user which is categorized by the medium of transmission used. The transmission technique involves multiplexing, de-multiplexing and PCM / STM frame formation to reach to digital hierarchy as described before. The type of signal at / within the access network may be analog or digital but transmission through all the mediums is always analog. Therefore the network analogy entirely depends on the transmission medium. There are mainly three types of transmission medium used in the transmission network i.e. metallic, optical and wireless medium.

6.3.2.1 Metallic Transmission Medium

There are mainly two forms of metallic medium i.e. balanced pair and coaxial pair. Balanced pair cables are used in the telecommunication network as junctions for interconnecting telephone exchanges and as subscriber cables to extend the connection from telephone exchange to subscriber premises. Coaxial cables are used in the telephone networks, cable TV networks and LAN or for computers communication. They are not used at frequencies lower than 60 KHz due to their degraded phase and cross talk properties.

6.3.2.2 Optical Transmission Medium

Optical transmission medium is generally the optical fiber which is a physical media and deals with optical / light signal. This is a recent addition in the transmission network system and found to be more suitable than others despite having few non technical limitations. Hence for last few years, optical fiber technology is fast replacing all other transmission media.

6.3.2.3 Wireless Transmission Medium

Wireless transmission medium is based on radio propagation physics through atmosphere. Depending on the frequency, radio systems are again categorized as HF, VHF, UHF and microwave system. HF, VHF and UHF radio systems are low channel capacity systems. They provide 1-30 speech channels per radio carrier. Terrestrials microwave systems are high capacity systems and provide the channel capacities of the order of 300 to 2700 channels per radio carrier. Satellite communication systems also operate in the microwave frequency range but provide extreme flexibility in terms of channel capacity and geographic location. Having capacities from 1-1800 channels per carrier, satellite earth stations are used in the telephone network.

6.4 Next Generation Network

Next Generation Networking (NGN) is a broad term to describe some key architectural evolutions in telecommunication core and access networks that will be deployed over the next 5-10 years. The general idea behind NGN is that one network transports all information and services (voice, data and all sorts of media such as video) by encapsulating these into packets, like it is on the Internet. NGN is commonly built around the internet protocol and therefore the term "all-IP" is also sometimes used to describe the transformation towards NGN.

6.4.1 Definition

According to ITU-T 'NGN is a packet-based network able to provide services including telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.

6.4.2 Architectural Changes for NGN

From a practical perspective, NGN involves two main architectural changes that need to be looked at separately:

a. In the core network, NGN implies a consolidation of several (dedicated or overlay) transport networks historically each built for a different service into one core transport network (often based on IP or Ethernet). It implies amongst others the migration of voice from a switched architecture (PSTN) to VoIP and also migration of legacy services such as X.25, frame relay.

b. In the wired / cable access network, NGN implies the migration from the 'dual' legacy voice to xDSL setup in the local exchanges to a converged setup in which the DSLAMs integrate voice ports or VoIP, allowing to remove the voice switching infrastructure from the exchange. NGN convergence implies migration of constant bit rate voice to packet cable standards that provide VoIP and session initiation protocol (SIP) services.

6.4.3 Underlying Technology Components

NGN are based on internet technologies including IP and Multi Protocol Label Switching (MPLS). At the application level, SIP seems to be taking over from ITU-T H.323. Following components work in the NGN network:

a. Softswitch - It is a programmable device that controls VoIP calls and enables correct integration of different protocols within NGN. The most important function of the softswitch is creating the interface to the existing telephone network, PSTN through signaling gateways (SG) and media gateways (MG).

b. Gatekeeper and Media Gateway Controller - Gatekeeper in NGN was originally a VoIP device, which converted voice and data from their analog or digital switched-circuit form (PSTN, SS7) to the packet-based one (IP) using gateways. It used to control one or more gateways. As soon as this kind of device started using the media gateway control protocol (MGCP), the name was changed to media gateway controller (MGC).

c. Call Agent - It is a general name for systems controlling calls.

d. IP Multimedia Subsystem (IMS) - It is a standardized NGN architecture for an internet media-services capability defined by the ETSI and the 3rd generation partnership project (3GPP).

6.5 Compatibility and Possible Migration

Analyzing the above it is perceived that NGN shall be an IP based network or shall work on packet switching principle. Therefore whenever a service provider wants to enable a new service, they can do so by defining it directly at the service layer without considering the transport layer i.e. services are independent of transport details. Increasingly, applications including voice will tend to be independent of the access network and will reside more on end-user devices.

Although SDH based transmission network when designed will be based on circuit switching principle yet inputs from the next generation access network will be effectively transported by the same without any critical deviation. Therefore any SDH based transmission network if designed properly will be compatible with the NGN. At best for complete migration to NGN technology may necessitate replacing the SDH radio with the ATM radio and no other significant changes shall be required in this connection especially on the infrastructure and other design set up since in both cases radio propagation phenomenon will be identical. Hence there will be a comfortable migration to the NGN.

6.6 Summary

NGN holds tremendous potentials promising to merge the transmission of data, voice, video and other media onto a single network. This will be the standard network infrastructure for the next 10 to 20 years. In NGN, services are independent of transport details. Therefore any SDH based transmission network if designed properly will be compatible with NGN and comfortable migration will be also possible.

END OF CHAPTER

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

7.1 Conclusion of this Study

Basing on radio propagation physics, radio link engineering, ITU transmission performance target, system design requirements and physical site survey, an SDH based microwave digital radio core network has been designed for tri-services organizations. Special attention is given on essential factors like radio, antenna systems, bit error rate, polarization, terrain roughness, rain effect, ITU performance and availability objectives while designing links by using path calculation software. 'Microwave Link Evaluation Software' has also been developed to assess the performance of the designed links. The developed software performs the analytical comparisons of the performance of the designed links with the ITU published transmission standard. The results encompass the following:

a. Microwave radio systems meet international carrier transmission standards and assure the required reliability and QoS.

b. Microwave radio systems can overcome the potentially detrimental propagation effects if designed / engineered precisely.

This paper shall also serve as an 'implementation tool' for future SDH based digital microwave transmission infrastructure setup for backbone network of any organization. 'Tri-services Organizations' of Ministry of Defense can implement this core radio network plan for their own use which will be redundant for other operators during peace time need. This work can also be used to test performance of similar networks designed by others involving multi vendor equipment.

7.2 Recommendations for Future Work

To get the actual reflection of the terrain, rain, temperature and climate / weather effect in the link budget calculation, we need to feed more accurate local data of Bangladesh in the microwave link budget software. Therefore I recommend following works to be done in future particularly for Bangladesh to combat the potentially detrimental propagation effect:

a. Terrain, rain and temperature analysis.

b. Climate / weather condition analysis including the related peculiarities.

END OF CHAPTER

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Appendix-A
(Path Profile Reports of Different Links)

Field	Dhaka	Sonargaon	Remark
Latitude	23°50'18.20"N	23°38'15.40"N	
Longitude	090°23'13.70"E	090°35'54.00"E	
Elevation(m)	**17.15**	**8.67**	
True azimuth(°)	135.88	315.96	
Path Length(km)	**30.95**		Path & Sites Analysis Report
Roughness(m)	**43**		
Gradient (%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	Equipment Analysis Report - Radio Part
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**35**	**40**	
Diversity Ant. Centerline(m)	25	30	Equipment Analysis Report - Ant. Part
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	37	42	
Ant. Polarization	Vertical		
Free Space Loss(dB)	140.9		
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	2.2	2.5	Loss & Gain Analysis Report
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	58.5		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-34.5**	Fade Margin Composite (dB)	33
Fade Margin-Flat(dB)	33.5		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999961	0.000039	
Annual One Way(Multipath)	99.999981	0.000019	6
Annual Two Way(Multipath)	99.999961	0.000039	12
Annual Rainfall	99.999971	0.000029	9
Total Annual One Way	99.999951	0.000049	15
Total Annual Two Way	99.999932	0.000068	21

Field	Sonargaon	Muradnagar	Remark
Latitude	23°38'15.40"N	23°38'10.00"N	
Longitude	090°35'54.00"E	090°58'07.00"E	
Elevation(m)	8.67	12.6	
True azimuth(°)	90.18	270.33	
Path Length(km)	**37.78**		**Path & Sites**
Roughness(m)	**15**		**Analysis Report**
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis**
Rx Threshold(dBm)	**-68**	**-68**	**Report - Radio Part**
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	18	44	
Diversity Ant. Centerline(m)	10	34	**Equipment Analysis**
Tx Line Type	EW 77 Ellip		**Report - Ant. Part**
Tx Line Length(m)	20	36	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.6		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.2	2.6	**Loss & Gain**
Branching Loss(dB)	0.5	0	**Analysis Report**
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.6		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.6**	**Fade Margin**	35.4
Fade Margin-Flat(dB)	36.4	**Composite (dB)**	
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999982**	**0.000018**	
Annual One Way(Multipath)	**99.999994**	**0.000006**	**2**
Annual Two Way(Multipath)	**99.999987**	**0.000013**	**4**
Annual Rainfall	**99.999974**	**0.000024**	**8**
Total Annual One Way	**99.999967**	**0.000033**	**10**
Total Annual Two Way	**99.999961**	**0.000039**	**12**

Field	Muradnagar	Comilla	Remark
Latitude	23° 38' 10.00" N	23° 27' 48.90 " N	Path & Sites Analysis Report
Longitude	090° 58' 07.00" E	091° 11' 14.00" E	
Elevation(m)	**12.6**	**19**	
True azimuth(°)	130.52	310.61	
Path Length(km)	**29.38**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**4**	**7**	
Diversity Ant. Centerline(m)	0	0	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	6	9	
Ant. Polarization	Vertical		
Free Space Loss(dB)	140.4		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.4	0.5	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.3		

	Performance	Analysis	
Rx Signal Level(dBm)	**-30.3**	Fade Margin Composite (dB)	36.6
Fade Margin-Flat(dB)	37.7		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999991**	**0.000009**	
Annual One Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Two Way(Multipath)	**99.999993**	**0.000007**	**2**
Annual Rainfall	**99.999987**	**0.000013**	**4**
Total Annual One Way	**99.999984**	**0.000026**	**5**
Total Annual Two Way	**99.99998**	**0.00002**	**6**

Field	Comilla	Choddogram	Remark
Latitude	23° 27' 48.90 " N	23° 10' 48.75 " N	Path & Sites Analysis Report
Longitude	091° 11' 14.00" E	091° 19' 08.85" E	
Elevation(m)	19	10.25	
True azimuth(°)	156.71	336.76	
Path Length(km)	**34.16**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	10	8	
Diversity Ant. Centerline(m)	0	0	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	12	10	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.7		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.7	0.6	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	52.2		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-28.2**	**Fade Margin Composite (dB)**	38.1
Fade Margin-Flat(dB)	39.8		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999989	0.000011	
Annual One Way(Multipath)	99.999996	0.000014	1
Annual Two Way(Multipath)	99.999991	0.000009	3
Annual Rainfall	99.999987	0.000013	4
Total Annual One Way	99.999983	0.000017	5
Total Annual Two Way	99.999978	0.000022	7

Field	Choddogram	Chagolnaiya	Remark
Latitude	23° 10' 48.75 " N	23° 02' 50.20 " N	
Longitude	091° 19' 08.85" E	091° 25' 46.80" E	
Elevation(m)	10.25	5.34	
True azimuth(°)	142.41	322.45	
Path Length(km)	**18.57**		**Path & Sites Analysis Report**
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	1.8	1.8	
Diversity Ant Dia(m)	1.2	1.2	
Primary Ant. Centerline(m)	10	10	
Diversity Ant. Centerline(m)	4	4	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	12	12	
Ant. Polarization	Vertical		
Free Space Loss(dB)	136.4		
Atm. Attenuation(dB)	0.2		
Line Loss(dB)	0.7	0.7	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	41.4	41.4	
Diversity Ant. Gain(dBi)	37.9	37.9	
Net Path Loss(dB)	55.8		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-36.8**	**Fade Margin Composite (dB)**	30.9
Fade Margin-Flat(dB)	31.2		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999998**	**0.000002**	
Annual One Way(Multipath)	**99.999999**	**0.000001**	**<1**
Annual Two Way(Multipath)	**99.999998**	**0.000002**	**<1**
Annual Rainfall	**99.999997**	**0.000003**	**<1**
Total Annual One Way	**99.999996**	**0.000004**	**1**
Total Annual Two Way	**99.999995**	**0.000005**	**2**

Field	Chagolnaiya	Mirshorai	Remark
Latitude	23° 02' 50.20 " N	22° 46' 38.00 " N	
Longitude	091° 25' 46.80" E	091° 34' 18.00" E	
Elevation(m)	**5.34**	**8.33**	
True azimuth(°)	154	334.06	
Path Length(km)	**33.26**		Path & Sites Analysis Report
Roughness(m)	**43**		
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	Equipment Analysis Report - Radio Part
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**16**	**28**	
Diversity Ant. Centerline(m)	8	20	Equipment Analysis Report - Ant. Part
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	18	30	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.5		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.1	1.8	Loss & Gain Analysis Report
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	**57.4**		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-33.4**	**Fade Margin Composite (dB)**	34
Fade Margin-Flat(dB)	34.6		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999978**	**0.000022**	
Annual One Way(Multipath)	99.999992	0.00008	3
Annual Two Way(Multipath)	99.999983	0.000017	5
Annual Rainfall	**99.999973**	**0.000027**	**9**
Total Annual One Way	99.999964	0.000036	11
Total Annual Two Way	**99.999956**	**0.000044**	**14**

Field	Mirshorai	Kumira	Remark
Latitude	22° 46' 38.00 " N	22° 31' 01.78 " N	Path & Sites Analysis Report
Longitude	091° 34' 18.00" E	091° 42' 41.58" E	
Elevation(m)	**8.33**	**44.84**	
True azimuth(°)	153.44	333.49	
Path Length(km)	**32.19**		
Roughness(m)	**43**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**8**	**6**	
Diversity Ant. Centerline(m)	2	2	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10	8	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.2		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.6	0.5	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	57.4		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.3**	Fade Margin Composite (dB)	35.8
Fade Margin-Flat(dB)	36.7		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	99.999992	0.000008	
Annual One Way(Multipath)	99.999997	0.000003	<1
Annual Two Way(Multipath)	99.999995	0.000005	2
Annual Rainfall	99.999944	0.000056	18
Total Annual One Way	99.999941	0.000059	19
Total Annual Two Way	99.999939	0.000061	19

Field	Kumira	Chittagong	Remark
Latitude	22° 31' 01.78 " N	22° 19' 28.00 " N	Path & Sites Analysis Report
Longitude	091° 42' 41.58" E	091° 48' 40.50" E	
Elevation(m)	**44.84**	**9.8**	
True azimuth(°)	154.29	334.33	
Path Length(km)	**23.68**		
Roughness(m)	**43**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**6**	**48**	
Diversity Ant. Centerline(m)	2	40	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	8	50	
Ant. Polarization	Vertical		
Free Space Loss(dB)	138.5		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.5	2.9	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.9		

	Performance	Analysis	
Rx Signal Level(dBm)	**-30.9**	Fade Margin Composite (dB)	36.1
Fade Margin-Flat(dB)	37.1		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999995**	**0.000005**	
Annual One Way(Multipath)	**99.999998**	**0.000002**	**<1**
Annual Two Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Rainfall	**99.999965**	**0.000035**	**11**
Total Annual One Way	**99.999963**	**0.000037**	**12**
Total Annual Two Way	**99.999962**	**0.000038**	**12**

Field	Chittagong	Chondhonesh	Remark
Latitude	22° 19' 28.00 " N	22° 12' 42.00 " N	
Longitude	091° 48' 40.50" E	092° 00' 53.00" E	
Elevation(m)	9.8	11.45	
True azimuth(°)	120.74	300.81	
Path Length(km)	24.41		Path & Sites Analysis Report
Roughness(m)	43		
Gradient(%)	15		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	24	24	Equipment Analysis Report - Radio Part
Rx Threshold(dBm)	-68	-68	
Rx Threshold BER	10EXP- 06	10EXP- 06	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	28	8	
Diversity Ant. Centerline(m)	20	2	Equipment Analysis Report - Ant. Part
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	30	10	
Ant. Polarization	Vertical		
Free Space Loss(dB)	138.8		
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	1.8	0.6	Loss & Gain Analysis Report
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.1		

	Performance	Analysis	
Rx Signal Level(dBm)	-30.1	Fade Margin Composite (dB)	36.7
Fade Margin-Flat(dB)	37.9		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999997	0.000003	
Annual One Way(Multipath)	99.999999	0.000001	<1
Annual Two Way(Multipath)	99.999998	0.000002	<1
Annual Rainfall	99.999967	0.000033	10
Total Annual One Way	99.999966	0.000034	11
Total Annual Two Way	99.999965	0.000035	11

Field	Chondhonesh	Lohagora	Remark
Latitude	22° 12' 42.00 " N	21° 58' 05.20 " N	
Longitude	092° 00' 53.00" E	092° 04' 24.00" E	
Elevation(m)	**11.45**	**19.87**	
True azimuth(°)	167.35	347.37	
Path Length(km)	**27.64**		**Path & Sites**
Roughness(m)	**43**		**Analysis Report**
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis**
Rx Threshold(dBm)	**-68**	**-68**	**Report - Radio Part**
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**5**	**13**	
Diversity Ant. Centerline(m)	0	5	**Equipment Analysis**
Tx Line Type	EW 77 Ellip		**Report - Ant. Part**
Tx Line Length(m)	7	15	
Ant. Polarization	Vertical		
Free Space Loss(dB)	139.9		
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.4	0.9	**Loss & Gain**
Branching Loss(dB)	0.5	0	**Analysis Report**
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.2		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30.2**	**Fade Margin**	36.7
Fade Margin-Flat(dB)	37.8	**Composite (dB)**	
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999995**	**0.000005**	
Annual One Way(Multipath)	**99.999998**	**0.000002**	**<1**
Annual Two Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Rainfall	**99.99996**	**0.00004**	**13**
Total Annual One Way	**99.999958**	**0.000042**	**13**
Total Annual Two Way	**99.999956**	**0.000044**	**14**

Field	Lohagora	Chiringa	Remark
Latitude	21° 58' 05.20 " N	21° 44' 57.30 " N	Path & Sites Analysis Report
Longitude	092° 04' 24.00" E	092° 04' 11.10" E	
Elevation(m)	**19.87**	**7**	
True azimuth(°)	180.88	0.88	
Path Length(km)	**24.24**		
Roughness(m)	**43**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	1.8	1.8	
Primary Ant. Centerline(m)	**6**	**5**	
Diversity Ant. Centerline(m)	0	0	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	8	7	
Ant. Polarization	Vertical		
Free Space Loss(dB)	138.7		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.5	0.4	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	41.4	41.4	
Net Path Loss(dB)	52.6		

	Performance	Analysis	
Rx Signal Level(dBm)	**-28.6**	Fade Margin Composite (dB)	37.8
Fade Margin-Flat(dB)	39.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999997	0.000003	
Annual One Way(Multipath)	99.999999	0.000001	<1
Annual Two Way(Multipath)	99.999998	0.000002	<1
Annual Rainfall	99.999973	0.000027	9
Total Annual One Way	99.999972	0.000028	9
Total Annual Two Way	99.999971	0.000029	9

Field	Chiringa	Idgaon	Remark
Latitude	21° 44' 57.30 " N	21° 32' 48.00 " N	Path & Sites Analysis Report
Longitude	092° 04' 11.10" E	092° 04' 14.80" E	
Elevation(m)	**7**	**17.68**	
True azimuth(°)	179.73	359.73	
Path Length(km)	**22.43**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	N (ITU)		
Climate	Coastal		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	1.8	1.8	
Primary Ant. Centerline(m)	**6**	**6**	
Diversity Ant. Centerline(m)	2	2	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	8	8	
Ant. Polarization	Vertical		
Free Space Loss(dB)	138.1		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.2		
Line Loss(dB)	0.5	0.5	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	52		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-28**	Fade Margin Composite (dB)	38.3
Fade Margin-Flat(dB)	40		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999998**	**0.000002**	
Annual One Way(Multipath)	**99.999999**	**0.000001**	**<1**
Annual Two Way(Multipath)	**99.999999**	**0.000001**	**<1**
Annual Rainfall	**99.999978**	**0.000022**	**7**
Total Annual One Way	**99.999978**	**0.000022**	**7**
Total Annual Two Way	**99.999977**	**0.000023**	**7**

Field	Idgaon	Cox's Bazzar	Remark
Latitude	21° 32' 48.00 " N	21° 26' 15.00 " N	Path & Sites Analysis Report
Longitude	092° 04' 14.80" E	091° 59' 47.00" E	
Elevation(m)	**17.68**	**1.17**	
True azimuth(°)	212.54	32.51	
Path Length(km)	**14.34**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Coastal		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	1.2	1.2	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	1.2	1.2	
Primary Ant. Centerline(m)	**6**	**6**	
Diversity Ant. Centerline(m)	2	2	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	8	8	
Ant. Polarization	Vertical		
Free Space Loss(dB)	134.2		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.2		
Line Loss(dB)	0.5	0.5	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	37.9	37.9	
Diversity Ant. Gain(dBi)	37.9	37.9	
Net Path Loss(dB)	60		

	Performance	**Analysis**	
Rx Signal Level(dBm)	**-36**	**Fade Margin Composite (dB)**	31.6
Fade Margin-Flat(dB)	32		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999999**	**0.000001**	
Annual One Way(Multipath)	**100**	**0**	**<1**
Annual Two Way(Multipath)	**99.999999**	**0.000001**	**<1**
Annual Rainfall	**99.99997**	**0.00003**	**9**
Total Annual One Way	**99.99997**	**0.00003**	**9**
Total Annual Two Way	**99.99997**	**0.00003**	**10**

Field	Dhaka	Dohar	Remark
Latitude	23° 50' 18.20" N	23° 37' 07.47" N	
Longitude	090° 23' 13.70" E	090° 07' 05.85" E	
Elevation(m)	**17.15**	**12.97**	
True azimuth(°)	228.47	48.36	
Path Length(km)	**36.65**		**Path & Sites Analysis Report**
Roughness(m)	**15**		
Gradient(%)	**6**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**36**	**20**	
Diversity Ant. Centerline(m)	28	12	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	36.5	20.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.3		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	2.1	1.2	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54.9		

	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30.9**	**Fade Margin Composite (dB)**	36.1
Fade Margin-Flat(dB)	37.1		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999982	0.000018	
Annual One Way(Multipath)	99.999993	0.000007	2
Annual Two Way(Multipath)	99.999987	0.000013	4
Annual Rainfall	99.999978	0.000022	7
Total Annual One Way	99.999971	0.000029	9
Total Annual Two Way	99.999964	0.000036	11

Field	Dohar	Maksudpur	Remark
Latitude	23° 37' 07.47" N	23° 20' 30.41" N	Path & Sites Analysis Report
Longitude	090° 07' 05.85" E	089° 52' 26.08" E	
Elevation(m)	**12.97**	**7.78**	
True azimuth(°)	219.19	39.09	
Path Length(km)	**39.55**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**48**	
Diversity Ant. Centerline(m)	2	40	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	48.2	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	2.8	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.7		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.7**	**Fade Margin Composite (dB)**	35.4
Fade Margin-Flat(dB)	36.3		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999979	0.000021	
Annual One Way(Multipath)	99.999992	0.000008	2
Annual Two Way(Multipath)	99.999985	0.000015	5
Annual Rainfall	99.999971	0.000029	9
Total Annual One Way	99.999964	0.000036	11
Total Annual Two Way	99.999956	0.000044	14

Field	Maksudpur	Noraiel	Remark
Latitude	23° 20' 30.41" N	23° 12' 15.19" N	Path & Sites Analysis Report
Longitude	089° 52' 26.08" E	089° 32' 28.11" E	
Elevation(m)	7.78	4	
True azimuth(°)	245.96	65.83	
Path Length(km)	37.3		
Roughness(m)	6		
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	24	24	
Rx Threshold(dBm)	-68	-68	
Rx Threshold BER	10EXP- 06	10EXP- 06	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	10	30	
Diversity Ant. Centerline(m)	2	22	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	30.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.5		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.8	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54.1		

	Performance	Analysis	
Rx Signal Level(dBm)	-30.1	Fade Margin Composite (dB)	36.7
Fade Margin-Flat(dB)	37.9		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999982	0.000018	
Annual One Way(Multipath)	99.999993	0.000007	2
Annual Two Way(Multipath)	99.999986	0.000014	5
Annual Rainfall	99.99998	0.00002	6
Total Annual One Way	99.999972	0.000028	9
Total Annual Two Way	99.999965	0.000035	11

Field	Noraiel	Jessore	Remark
Latitude	23° 12' 15.19" N	23° 09' 55.30" N	
Longitude	089° 32' 28.11" E	089° 12' 43.60" E	
Elevation(m)	4	12.34	
True azimuth(°)	262.78	82.66	
Path Length(km)	33.96		Path & Sites Analysis Report
Roughness(m)	6		
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	24	24	Equipment Analysis Report - Radio Part
Rx Threshold(dBm)	-68	-68	
Rx Threshold BER	10EXP- 06	10EXP- 06	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	30	41	
Diversity Ant. Centerline(m)	22	33	Equipment Analysis Report - Ant. Part
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	30.5	41.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.7		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.8	2.4	Loss & Gain Analysis Report
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	59		

Performance Analysis

Rx Signal Level(dBm)	-35	Fade Margin Composite (dB)	32.6
Fade Margin-Flat(dB)	33		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999961	0.000039	
Annual One Way(Multipath)	99.999986	0.000014	5
Annual Two Way(Multipath)	99.999971	0.000029	9
Annual Rainfall	99.999963	0.000037	12
Total Annual One Way	99.999948	0.000052	16
Total Annual Two Way	99.999934	0.000066	21

Field	Jessore	Noapara	Remark
Latitude	23° 09' 55.30 " N	23° 01' 10.00 " N	Path & Sites Analysis Report
Longitude	089° 12' 43.60" E	089° 22' 52.00" E	
Elevation(m)	**12.34**	**7**	
True azimuth(°)	132.99	313.06	
Path Length(km)	**23.68**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	N (ITU)		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**6**	**48**	
Diversity Ant. Centerline(m)	2	40	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	8	50	
Ant. Polarization	Vertical		
Free Space Loss(dB)	138.5		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.5	2.9	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.9		

	Performance	Analysis	
Rx Signal Level(dBm)	**-30.9**	**Fade Margin Composite (dB)**	36.1
Fade Margin-Flat(dB)	37.1		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999998	0.000002	
Annual One Way(Multipath)	99.999999	0.000001	<1
Annual Two Way(Multipath)	99.999999	0.000001	<1
Annual Rainfall	99.999965	0.000035	11
Total Annual One Way	99.999965	0.000035	11
Total Annual Two Way	99.999964	0.000036	11

Field	Noapara	Khulna	Remark
Latitude	23° 01' 10.00" N	22° 47' 53.22 " N	Path & Sites Analysis Report
Longitude	089° 22' 52.00" E	089° 33' 14.05" E	
Elevation(m)	7	**6**	
True azimuth(°)	144.09	324.16	
Path Length(km)	**30.25**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**4**	**7**	
Diversity Ant. Centerline(m)	0	0	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	4.5	7.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	140.7		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.3	0.4	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.9		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30.4**	Fade Margin Composite (dB)	36.5
Fade Margin-Flat(dB)	37.6		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999985	0.000015	
Annual One Way(Multipath)	99.999992	0.000002	3
Annual Two Way(Multipath)	99.999984	0.000016	5
Annual Rainfall	99.999954	0.000046	15
Total Annual One Way	99.999945	0.000055	17
Total Annual Two Way	99.999937	0.000063	20

Field	Khulna	Mongla	Remark
Latitude	22° 47' 53.22" N	22° 28' 07.18" N	Path & Sites Analysis Report
Longitude	089° 33' 14.05" E	089° 35' 14.95" E	
Elevation(m)	**6**	**0**	
True azimuth(°)	174.59	354.6	
Path Length(km)	**36.65**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**30**	
Diversity Ant. Centerline(m)	2	22	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	30.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.3		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.8	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	**45.8**	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30**	**Fade Margin Composite (dB)**	36.8
Fade Margin-Flat(dB)	38		

Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999983**	**0.000017**	
Annual One Way(Multipath)	**99.999993**	**0.000007**	**2**
Annual Two Way(Multipath)	**99.999986**	**0.000014**	**4**
Annual Rainfall	**99.999945**	**0.000055**	**17**
Total Annual One Way	**99.999938**	**0.000062**	**20**
Total Annual Two Way	**99.999931**	**0.000069**	**22**

Field	Dhaka	Savar	Remark
Latitude	23° 50' 18.20 " N	23° 55' 14.00 " N	Path & Sites Analysis Report
Longitude	090° 23' 13.70" E	090° 16' 25.00" E	
Elevation(m)	17.15	12.54	
True azimuth(°)	308.23	128.18	
Path Length(km)	**14.71**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	1.2	1.2	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	1.2	1.2	
Primary Ant. Centerline(m)	10	10	
Diversity Ant. Centerline(m)	4	4	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	10.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	134.4		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.2		
Line Loss(dB)	0.6	0.6	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	37.9	37.9	
Diversity Ant. Gain(dBi)	37.9	37.9	
Net Path Loss(dB)	60.6		

Performance Analysis

Rx Signal Level(dBm)	**-36.6**	Fade Margin Composite (dB)	31.2
Fade Margin-Flat(dB)	31.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999997	0.000003	
Annual One Way(Multipath)	99.999999	0.000001	<1
Annual Two Way(Multipath)	99.999998	0.000002	<1
Annual Rainfall	99.999996	0.000004	1
Total Annual One Way	99.999995	0.000005	2
Total Annual Two Way	99.999994	0.000006	2

Field	Savar	Giaor	Remark
Latitude	23° 55' 14.00" N	23° 54' 01.00" N	
Longitude	090° 16' 25.00" E	089° 53' 30.00" E	
Elevation(m)	**12.54**	**12.52**	
True azimuth(°)	266.77	86.62	
Path Length(km)	**38.96**		**Path & Sites Analysis Report**
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**32**	
Diversity Ant. Centerline(m)	2	24	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	32.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.9		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.9	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54.6		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30.6**	**Fade Margin Composite (dB)**	36.3
Fade Margin-Flat(dB)	37.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999979**	**0.000021**	
Annual One Way(Multipath)	**99.999992**	**0.000008**	**2**
Annual Two Way(Multipath)	**99.999984**	**0.000016**	**5**
Annual Rainfall	**99.999876**	**0.000024**	**8**
Total Annual One Way	**99.999968**	**0.000032**	**10**
Total Annual Two Way	**99.99996**	**0.00004**	**12**

Field	Giaor	Sathyia	Remark
Latitude	23° 54' 01.00" N	24° 03' 27.10" N	Path & Sites Analysis Report
Longitude	089° 53' 30.00" E	089° 32' 59.00" E	
Elevation(m)	**12.52**	**13.72**	
True azimuth(°)	296.66	116.52	
Path Length(km)	**38.91**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**32**	
Diversity Ant. Centerline(m)	2	24	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	32.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.9		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.9	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54.6		

	Performance	Analysis	
Rx Signal Level(dBm)	**-30.6**	Fade Margin Composite (dB)	36.3
Fade Margin-Flat(dB)	37.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.99998	0.00002	
Annual One Way(Multipath)	99.999992	0.000008	2
Annual Two Way(Multipath)	99.999985	0.000015	5
Annual Rainfall	99.999976	0.000024	8
Total Annual One Way	99.999969	0.000031	10
Total Annual Two Way	99.999961	0.000039	12

Field	Sathyia	Atghoria	Remark
Latitude	24° 03' 27.10" N	24° 05' 03.90" N	
Longitude	089° 32' 59.00" E	089° 13' 07.00" E	
Elevation(m)	**13.72**	**16**	
True azimuth(°)	276.12	94.99	
Path Length(km)	**33.8**		**Path & Sites Analysis Report**
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**30**	**41**	
Diversity Ant. Centerline(m)	22	33	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	30.5	41.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.6		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.8	2.4	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.1		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.1**	**Fade Margin Composite (dB)**	36
Fade Margin-Flat(dB)	36.9		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999984	0.000016	
Annual One Way(Multipath)	99.999994	0.000006	2
Annual Two Way(Multipath)	99.999988	0.000012	4
Annual Rainfall	99.999981	0.000019	6
Total Annual One Way	99.999974	0.000026	9
Total Annual Two Way	99.999968	0.000032	10

Field	Atghoria	Bagha	Remark
Latitude	24° 05' 03.90" N	24° 11' 36.00" N	
Longitude	089° 13' 07.00" E	088° 50' 10.00" E	
Elevation(m)	**16**	**20.14**	
True azimuth(°)	287.32	107.16	
Path Length(km)	**40.71**		**Path & Sites Analysis Report**
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**20**	**45**	
Diversity Ant. Centerline(m)	12	37	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	20.5	45.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.2		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.2	2.7	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.1		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-32.4**	**Fade Margin Composite (dB)**	34.9
Fade Margin-Flat(dB)	35.6		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999964**	**0.000036**	
Annual One Way(Multipath)	**99.999987**	**0.000013**	**4**
Annual Two Way(Multipath)	**99.999974**	**0.000026**	**8**
Annual Rainfall	**99.999967**	**0.000033**	**10**
Total Annual One Way	**99.999954**	**0.000046**	**15**
Total Annual Two Way	**99.99994**	**0.00006**	**19**

Field	Bagha	Rajshahi	Remark
Latitude	24° 11' 36.00" N	24° 22' 04.40" N	
Longitude	088° 50' 10.00" E	088° 36' 26.00" E	
Elevation(m)	**20.14**	**23.2**	
True azimuth(°)	309.81	129.71	
Path Length(km)	**30.23**		**Path & Sites Analysis Report**
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**4**	**7**	
Diversity Ant. Centerline(m)	0	0	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	4.5	7.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	140.7		
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.3	0.4	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	54.4		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-30.4**	**Fade Margin Composite (dB)**	36.5
Fade Margin-Flat(dB)	37.6		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999989**	**0.000011**	
Annual One Way(Multipath)	**99.999995**	**0.000005**	**2**
Annual Two Way(Multipath)	**99.99999**	**0.00001**	**3**
Annual Rainfall	**99.999986**	**0.000014**	**4**
Total Annual One Way	**99.999981**	**0.000019**	**6**
Total Annual Two Way	**99.999977**	**0.000023**	**7**

Field	Dhaka	Mirzapur	Remark
Latitude	23° 50' 18.20" N	24° 06' 08.80" N	Path & Sites Analysis Report
Longitude	090° 23' 13.70" E	090° 05' 38.00" E	
Elevation(m)	**17.15**	**14.05**	
True azimuth(°)	314.48	134.36	
Path Length(km)	**41.79**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**40**	**8**	
Diversity Ant. Centerline(m)	32	0	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	40.5	8.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.5		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.5		
Line Loss(dB)	2.4	0.5	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.6		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.6**	**Fade Margin Composite (dB)**	35.5
Fade Margin-Flat(dB)	36.4		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	99.999974	0.000026	
Annual One Way(Multipath)	99.99999	0.00001	3
Annual Two Way(Multipath)	99.999981	0.000019	6
Annual Rainfall	99.999969	0.000031	10
Total Annual One Way	99.99996	0.00004	13
Total Annual Two Way	99.99995	0.00005	16

Field	Mirzapur	Ghatail	Remark
Latitude	24° 06' 08.80" N	24° 28' 36.44" N	Path & Sites Analysis Report
Longitude	090° 05' 38.00" E	089° 59' 26.27" E	
Elevation(m)	**14.05**	**15.11**	
True azimuth(°)	345.83	165.79	
Path Length(km)	**42.77**		
Roughness(m)	**15**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**20**	**50**	
Diversity Ant. Centerline(m)	12	42	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	20.5	50.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.7		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.5		
Line Loss(dB)	1.2	3	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	57.1		

	Performance	Analysis	
Rx Signal Level(dBm)	**-33.1**	Fade Margin Composite (dB)	34.2
Fade Margin-Flat(dB)	349		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999934	0.000066	
Annual One Way(Multipath)	99.999975	0.000025	8
Annual Two Way(Multipath)	99.999951	0.000049	15
Annual Rainfall	99.99996	0.00004	13
Total Annual One Way	99.999935	0.000065	20
Total Annual Two Way	99.999911	0.000089	28

Field	Ghatail	Kazipur	Remark
Latitude	24° 28' 36.44" N	24° 39' 37.80" N	Path & Sites Analysis Report
Longitude	089° 59' 26.27" E	089° 38' 44.00" E	
Elevation(m)	**15.11**	**17.15**	
True azimuth(°)	300.28	120.13	
Path Length(km)	**40.45**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**20**	**50**	
Diversity Ant. Centerline(m)	12	42	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	20.5	50.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.2		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.2	3	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	56.6		

	Performance	Analysis	
Rx Signal Level(dBm)	**-32.6**	Fade Margin Composite (dB)	34.7
Fade Margin-Flat(dB)	35.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999967	0.000033	
Annual One Way(Multipath)	99.999988	0.000012	4
Annual Two Way(Multipath)	99.999976	0.000024	8
Annual Rainfall	99.999966	0.000034	11
Total Annual One Way	99.999954	0.000046	15
Total Annual Two Way	99.999942	0.000058	18

Field	Kazipur	Bogra	Remark
Latitude	24° 39' 37.80" N	24° 50' 35.00" N	
Longitude	089° 38' 44.00" E	089° 22' 33.00" E	
Elevation(m)	**17.15**	**26.74**	
True azimuth(°)	306.6	126.49	
Path Length(km)	**33.96**		**Path & Sites**
Roughness(m)	**6**		**Analysis Report**
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis**
Rx Threshold(dBm)	**-68**	**-68**	**Report - Radio Part**
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**15**	**21**	
Diversity Ant. Centerline(m)	7	13	**Equipment Analysis**
Tx Line Type	EW 77 Ellip		**Report - Ant. Part**
Tx Line Length(m)	15.5	21.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.7		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.9	1.3	**Loss & Gain**
Branching Loss(dB)	0.5	0	**Analysis Report**
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	53		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-29**	**Fade Margin**	37.5
Fade Margin-Flat(dB)	39	**Composite (dB)**	
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.99999**	**0.00001**	
Annual One Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Two Way(Multipath)	**99.999992**	**0.000008**	**2**
Annual Rainfall	**99.999986**	**0.000014**	**5**
Total Annual One Way	**99.999982**	**0.000018**	**6**
Total Annual Two Way	**99.999978**	**0.000022**	**7**

Field	Bogra	Gobindogonj	Remark
Latitude	24° 50' 35.00" N	25° 10' 30.00" N	
Longitude	089° 22' 33.00" E	089° 23' 18.00" E	
Elevation(m)	26.74	24.84	
True azimuth(°)	1.96	181.97	
Path Length(km)	36.79		Path & Sites Analysis Report
Roughness(m)	6		
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	24	24	Equipment Analysis Report - Radio Part
Rx Threshold(dBm)	-68	-68	
Rx Threshold BER	10EXP- 06	10EXP- 06	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	10	30	
Diversity Ant. Centerline(m)	2	22	Equipment Analysis Report - Ant. Part
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	30.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.4		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.8	Loss & Gain Analysis Report
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	54		

	Performance	Analysis	
Rx Signal Level(dBm)	-30	Fade Margin Composite (dB)	36.8
Fade Margin-Flat(dB)	38		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999984	0.000016	
Annual One Way(Multipath)	99.999994	0.000006	2
Annual Two Way(Multipath)	99.999988	0.000012	4
Annual Rainfall	99.999988	0.00002	6
Total Annual One Way	99.999874	0.000026	8
Total Annual Two Way	99.999968	0.000032	10

Field	Gobindogonj	Pirgonj	Remark
Latitude	25° 10' 30.00" N	25° 27' 08.00" N	Path & Sites Analysis Report
Longitude	089° 23' 18.00" E	089° 17' 52.00" E	
Elevation(m)	**24.84**	**28**	
True azimuth(°)	343.48	163.44	
Path Length(km)	**32.03**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**18**	
Diversity Ant. Centerline(m)	2	10	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	18.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.2		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.6	1.1	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	52.1		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-28.1**	**Fade Margin Composite (dB)**	38.2
Fade Margin-Flat(dB)	39.9		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999992	0.000008	
Annual One Way(Multipath)	99.999997	0.000003	< 1
Annual Two Way(Multipath)	99.999994	0.000006	2
Annual Rainfall	99.999962	0.000038	12
Total Annual One Way	99.999959	0.000041	13
Total Annual Two Way	99.999956	0.000044	14

Field	Pirgonj	Rangpur	Remark
Latitude	25° 27' 08.00" N	25° 44' 20.00" N	
Longitude	089° 17' 52.00" E	089° 13' 53.00" E	
Elevation(m)	**28**	**34.88**	
True azimuth(°)	348.15	168.13	
Path Length(km)	**32.45**		**Path & Sites Analysis Report**
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**18**	
Diversity Ant. Centerline(m)	2	10	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	18.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	141.3		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	1.1	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	52.2		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-28.2**	**Fade Margin Composite (dB)**	38.1
Fade Margin-Flat(dB)	39.8		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	99.999992	0.000008	
Annual One Way(Multipath)	99.999997	0.000003	< 1
Annual Two Way(Multipath)	99.999994	0.000006	2
Annual Rainfall	99.999961	0.000039	12
Total Annual One Way	99.999953	0.000042	13
Total Annual Two Way	99.999955	0.000045	14

Field	Ghatail	Fulbaria	Remark
Latitude Longitude Elevation(m) True azimuth(°) Path Length(km) Roughness(m) Gradient(%) Rainfall Area Climate Temperature(°C)	24° 28' 36.44" N 089° 59' 26.27" E **15.11** 66.39 **28.85** **6** **15** ITU Region N Average 30	24° 34' 51.73" N 090° 15' 05.90" E **15.81** 246.49	**Path & Sites Analysis Report**
Frequency Band(GHz) Radio Series Modulation Capacity Tx Power(dBm) Rx Threshold(dBm) Rx Threshold BER Dispersive Fade Margin(dB) Operating Mode	7/8 (8.5 GHz) ALTIUM SDH 128 QAM STM-1 **24** **-68** **10EXP- 06** 43 Space Diversity	7/8 (8.5 GHz) ALTIUM SDH 128 QAM STM-1 **24** **-68** **10EXP- 06** 43 Space Diversity	**Equipment Analysis Report - Radio Part**
Primary Ant. Dia(m) Diversity Ant Dia(m) Primary Ant. Centerline(m) Diversity Ant. Centerline(m) Tx Line Type Tx Line Length(m) Ant. Polarization	2.4 2.4 **10** 2 EW 77 Ellip 10.5 Vertical	2.4 2.4 **18** 10 18.5	**Equipment Analysis Report - Ant. Part**
Free Space Loss(dB) Atm. Attenuation(dB) Line Loss(dB) Branching Loss(dB) Primary Ant. Gain(dBi) Diversity Ant. Gain(dBi) Net Path Loss(dB)	140.3 0.3 0.6 0.5 43.9 43.9 55	 1.1 0 43.9 43.9	**Loss & Gain Analysis Report**

	Performance	**Analysis**	
Rx Signal Level(dBm) **Fade Margin-Flat(dB)**	**-31** 37	**Fade Margin Composite (dB)**	36

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.99999**	**0.00001**	
Annual One Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Two Way(Multipath)	**99.999993**	**0.000007**	**2**
Annual Rainfall	**99.999953**	**0.000047**	**15**
Total Annual One Way	**99.999949**	**0.000051**	**16**
Total Annual Two Way	**99.999946**	**0.000054**	**17**

Field	Fulbaria	Mymensingh	Remark
Latitude	24° 34' 51.73" N	24° 44' 48.00" N	
Longitude	090° 15' 05.90" E	090° 25' 13.00" E	
Elevation(m)	**15.81**	**12.36**	
True azimuth(°)	42.9	222.97	
Path Length(km)	**25.06**		**Path & Sites Analysis Report**
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	2.4	2.4	
Diversity Ant Dia(m)	2.4	2.4	
Primary Ant. Centerline(m)	**10**	**18**	
Diversity Ant. Centerline(m)	2	12	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	18.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	139		
Atm. Attenuation(dB)	0.3		
Line Loss(dB)	0.6	1.1	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	43.9	43.9	
Diversity Ant. Gain(dBi)	43.9	43.9	
Net Path Loss(dB)	53.7		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-29.7**	**Fade Margin Composite (dB)**	37
Fade Margin-Flat(dB)	38.3		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999995**	**0.000005**	
Annual One Way(Multipath)	**99.999998**	**0.000002**	**< 1**
Annual Two Way(Multipath)	**99.999996**	**0.000004**	**1**
Annual Rainfall	**99.999967**	**0.000033**	**10**
Total Annual One Way	**99.999965**	**0.000035**	**11**
Total Annual Two Way	**99.999963**	**0.000037**	**12**

Field	Dhaka	Norshindhi	Remark
Latitude	23° 50' 18.20" N	23° 55' 23.70" N	
Longitude	090° 23' 13.70" E	090° 45' 50.00" E	
Elevation(m)	**17.15**	**8**	
True azimuth(°)	76.16	256.31	
Path Length(km)	**39.51**		**Path & Sites**
Roughness(m)	**6**		**Analysis Report**
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis**
Rx Threshold(dBm)	**-68**	**-68**	**Report - Radio Part**
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**48**	
Diversity Ant. Centerline(m)	2	40	**Equipment Analysis**
Tx Line Type	EW 77 Ellip		**Report - Ant. Part**
Tx Line Length(m)	10.5	48.2	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	2.8	**Loss & Gain**
Branching Loss(dB)	0.5	0	**Analysis Report**
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.7		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.7**	**Fade Margin**	35.4
Fade Margin-Flat(dB)	36.3	**Composite (dB)**	
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	**99.999977**	**0.000023**	
Annual One Way(Multipath)	**99.999992**	**0.000008**	**3**
Annual Two Way(Multipath)	**99.999983**	**0.000017**	**5**
Annual Rainfall	**99.999971**	**0.000029**	**9**
Total Annual One Way	**99.999963**	**0.000037**	**12**
Total Annual Two Way	**99.999955**	**0.000045**	**14**

Field	Norshindhi	Soraiel	Remark
Latitude	23° 55' 23.70" N	24° 04' 23.00" N	Path & Sites Analysis Report
Longitude	090° 45' 50.00" E	091° 07' 04.55" E	
Elevation(m)	**8**	**8.43**	
True azimuth(°)	65.2	245.34	
Path Length(km)	**39.66**		
Roughness(m)	**6**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**48**	
Diversity Ant. Centerline(m)	2	40	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	48.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	2.8	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.7		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-31.7**	**Fade Margin Composite (dB)**	35.4
Fade Margin-Flat(dB)	36.3		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	99.99998	0.00002	
Annual One Way(Multipath)	99.999993	0.000007	2
Annual Two Way(Multipath)	99.999986	0.000014	4
Annual Rainfall	99.999971	0.000029	9
Total Annual One Way	99.999964	0.0000036	11
Total Annual Two Way	99.999957	0.0000043	13

Field	Soraiel	Hobigonj	Remark
Latitude	24° 04' 23.00" N	24° 20' 18.00" N	Path & Sites Analysis Report
Longitude	091° 07' 04.55" E	091° 23' 49.90" E	
Elevation(m)	8.43	11	
True azimuth(°)	43.94	224.05	
Path Length(km)	40.84		
Roughness(m)	6		
Gradient(%)	15		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	24	24	
Rx Threshold(dBm)	-68	-68	
Rx Threshold BER	10EXP- 06	10EXP- 06	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	20	45	
Diversity Ant. Centerline(m)	12	37	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	20.5	45.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.4		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	1.2	2.7	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	56.4		

	Performance	Analysis	
Rx Signal Level(dBm)	-32.4	Fade Margin Composite (dB)	34.9
Fade Margin-Flat(dB)	35.6		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	99.999961	0.000039	
Annual One Way(Multipath)	99.999986	0.000014	5
Annual Two Way(Multipath)	99.999971	0.000029	9
Annual Rainfall	99.999966	0.000034	11
Total Annual One Way	99.999952	0.000048	15
Total Annual Two Way	99.999938	0.000062	20

Field	Hobigonj	Moulovibazzar	Remark
Latitude	24° 20' 18.00" N	24° 31' 41.31" N	Path & Sites Analysis Report
Longitude	091° 23' 49.90" E	091° 45' 46.79" E	
Elevation(m)	**11**	**11.78**	
True azimuth(°)	60.38	240.53	
Path Length(km)	**42.64**		
Roughness(m)	**43**		
Gradient(%)	**15**		
Rainfall Area	ITU Region M		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	Equipment Analysis Report - Radio Part
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	Equipment Analysis Report - Ant. Part
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**20**	**50**	
Diversity Ant. Centerline(m)	12	42	
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	20.5	50.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	143.7		Loss & Gain Analysis Report
Atm. Attenuation(dB)	0.5		
Line Loss(dB)	1.2	3	
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	57.1		
	Performance	**Analysis**	
Rx Signal Level(dBm)	**-33.1**	**Fade Margin Composite (dB)**	34.3
Fade Margin-Flat(dB)	34.9		
Performance Field (ITU)	**Availability (%)**	**Outage (%)**	**Second/Year**
Worst Month(Multipath)	99.999937	0.000063	
Annual One Way(Multipath)	99.999976	0.000024	7
Annual Two Way(Multipath)	99.999953	0.000047	15
Annual Rainfall	99.99996	0.00004	13
Total Annual One Way	99.999937	0.000063	20
Total Annual Two Way	99.999913	0.000087	27

Field	Moulovibazzar	Sylhet	Remark
Latitude	24° 31' 41.31" N	24° 51' 35.33" N	
Longitude	091° 45' 46.79" E	091° 53' 39.09" E	
Elevation(m)	**11.78**	**12.62**	
True azimuth(°)	19.84	199.9	
Path Length(km)	**39.06**		**Path & Sites Analysis Report**
Roughness(m)	**43**		
Gradient(%)	**15**		
Rainfall Area	ITU Region N		
Climate	Average		
Temperature(°C)	30		
Frequency Band(GHz)	7/8 (8.5 GHz)	7/8 (8.5 GHz)	
Radio Series	ALTIUM SDH	ALTIUM SDH	
Modulation	128 QAM	128 QAM	
Capacity	STM-1	STM-1	
Tx Power(dBm)	**24**	**24**	**Equipment Analysis Report - Radio Part**
Rx Threshold(dBm)	**-68**	**-68**	
Rx Threshold BER	**10EXP- 06**	**10EXP- 06**	
Dispersive Fade Margin(dB)	43	43	
Operating Mode	Space Diversity	Space Diversity	
Primary Ant. Dia(m)	3	3	
Diversity Ant Dia(m)	3	3	
Primary Ant. Centerline(m)	**10**	**48**	
Diversity Ant. Centerline(m)	2	40	**Equipment Analysis Report - Ant. Part**
Tx Line Type	EW 77 Ellip		
Tx Line Length(m)	10.5	48.5	
Ant. Polarization	Vertical		
Free Space Loss(dB)	142.9		
Atm. Attenuation(dB)	0.4		
Line Loss(dB)	0.6	2.8	**Loss & Gain Analysis Report**
Branching Loss(dB)	0.5	0	
Primary Ant. Gain(dBi)	45.8	45.8	
Diversity Ant. Gain(dBi)	45.8	45.8	
Net Path Loss(dB)	55.6		

	Performance	**Analysis**	
Rx Signal Level(dBm)	**31.6**	**Fade Margin Composite (dB)**	35.5
Fade Margin-Flat(dB)	36.4		

Performance Field (ITU)	Availability (%)	Outage (%)	Second/Year
Worst Month(Multipath)	**99.999982**	**0.000018**	
Annual One Way(Multipath)	**99.999994**	**0.000006**	**2**
Annual Two Way(Multipath)	**99.999988**	**0.000012**	**4**
Annual Rainfall	**99.999929**	**0.000071**	**22**
Total Annual One Way	**99.999923**	**0.000077**	**24**
Total Annual Two Way	**99.999917**	**0.000083**	**26**