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Design of High Capacity Microwave Link between Two Cities

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ABSTRACT: Post 2000, Optical fibre media was deployed throughout the country by the Indian Cellular operators to meet the increase in Mobile Backhaul Traffic demand. Due to road expansion activities, fiber media is getting disconnected almost every day in different parts of the country. During such events, traffic is diverted to other sections of the fibre ring. Sometimes these Fibber links which are carrying additional traffic are getting choked due to overload. Augmentation of choked links or laying of additional fibre links are time consuming and sometimes not feasible due to Techno Commercial reasons. Hence Microwave links are being deployed to ease out the congestion. Design aspects of Microwave links for long hop lengths are different from for short hop length links. In this article various aspects required to be considered to engineer a long- hop length link spanning between two cities is presented. An attempt is made to practically design a long hop length MW link between two towns located in north Karnataka, India separated by a distance of 40Kms by road.

KEYWORDS: Mobile Backhaul, Point to Point Microwave link, Terrestrial, Line of Sight, Inter City,

I. INTRODUCTION

Point to Point Microwave (MW) links are fixed Line of sight (LOS) Terrestrial links operating in the frequency bands6 GHz to 30 GHz. Point to Point LOS links are different from other Wireless links like, point to point or Point to multi pointWi-Fi, WiMax,links namely LMDS (Local to Multi point distribution service) or MMDS (Multichannel to multipoint distribution service) ,which operate either in LOS or non LOS scenarios. Performance and Availability of Intercity MW links are to be comparable with that of Optical fiber links. Performance of short hop length MW links is mostly affected by rain attenuation and Long hop length links by daily, seasonal and annual weather variations. Atmospheric variations severely affect the performance due to elevated layer and ground layer reflections. Forgoing paragraphs summarise various aspects to be considered for the design of long hop length MW links [2],[6],[7][8].

A. *Advantages of Microwave media:*

- Can transport traffic capacity up to 2*STM1, SDH (126E1's)
- Can support distances from less than a KM to 40Kms in a single hop (6 GHz to 30 GHz) and in special cases, distances up to 120 Km from Mountain to mountain.
- Can easily be deployed in difficult terrain in short time as compared to Fiber.
- Ease of Upgradeability, redeploymentability
- Low maintenance cost (minimal recurring operational costs)

II. RELATED WORK

A. *Typical intercity Microwave Link:*

Fig.1 represents, a typical MW link covering long distance (long hop length). Link Consists of MW radio's operating in 6/7/8/ GHz, band, Tall Ground based towers of height ranging from 40M to 80M,(100M height towers used in special cases), high performance MW Parabolic dish Antennas and Feeder cable to interconnect antenna with radio.Majority of

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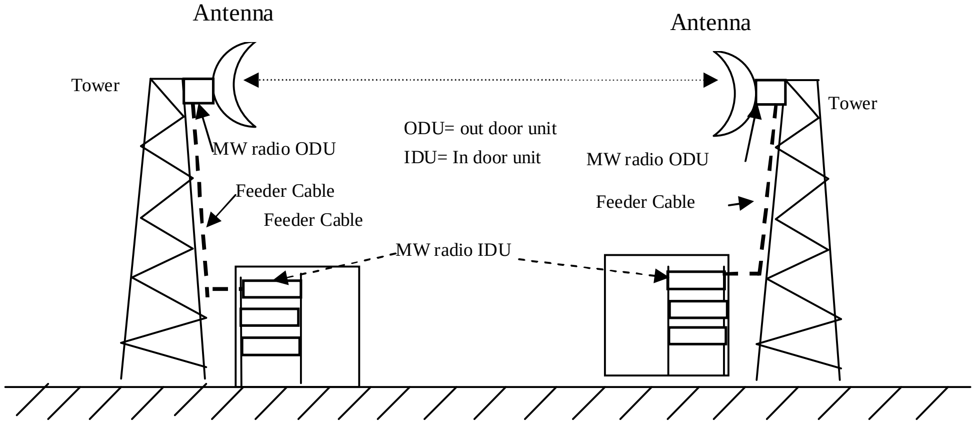
the MW radios are split mount type. Contain two parts, Outdoor unit (ODU) which is hermitically sealedRF Tran's receiver unit mounted directly with Antenna and another Indoor Unit (IDU) which ismounted inside a Shelter and contain Base band processing and modulator Demodulator circuits. Low loss Foam dielectric cable interconnects IDU



Fiig.1 Typical Microwave link

and ODU. PDH (Plesiochronous digital Hierarchy) low capacity radios (34 Mbps, QPSK modulation in 28MHz RF Band width) are used for last mile and low capacity routes where as SDH (synchronous digital Hierarchy) high capacity radios(155Mbps, 128QAM modulation in 28MHz RF Band width) are used Long hop length routes and sometimes in last mile connectivity routes also where high capacity is required.

B. *Rain attenuation:*

In general 6/7/8 GH z frequency bands are used for Long hop length intercity routes and 15/18/23 GHz used for short hop length last mile routes. Rain attenuation is one of the serious issues in Microwave links. Rain attenuation increases with increase in Hop length and the frequency. Frequency spectrum above 10 GHz is affected by rain attenuation [3]. Hence 6/7/8 GHz band are used for Intercity Long hop length (15 to 40KMs) routes. And 15/18/23 GHz for short distance (up to 10 Kms).Each country has their own frequency policy and in general follow ITU recommendations. Terrestrial point to Point MW frequency channel band width in India is 28 MHz. Information (voice, data, video) that has to be transmitted have to be with in one channel BW of 28MHz, irrespective of the data rate(34 Mbps to 155Mbps), hence higher order modulation schemes are used to confine the data rate with in 28MHz RF BW.

C. *Tall Towers :*

Since microwave communication is LOS communication, as the hop distance increases tower heights also increases to achieve LOS and to avoid earth bulge and the Physical obstructions, like tress, structures, buildings etc. falling on the LOS path. For a normal terrain, A minimum of 60M tower heights at both ends are required for a 30KM hop to obtain LOS .

If the terrain is hilly, tower heights may go up beyond 80M.some cases 100m also.

Theoretical tower heights can be calculated by using eq.(1), $d=3.57[\sqrt{Ht} + \sqrt{Hr}\ ]$ Km, ……eq.(1)

Where Ht and Hr is transmitting & receiving antenna heights (radius of earth=6370Kms). eq.(1) don't consider earth bulge and Fresnel zone clearances factors.(Refer II.D and II.E)

D. *Earth bulge :*

MW's travel in the lower part of the troposphere. Due to change in the atmospheric refractivity gradients, top portion of the wave front travel faster than the lower part. Due to this, wave travel additional distance. This additional distance is factored as earth bulge or K factor. For normal propagation conditions K=4/3 and for abnormal conditions K<1 or K>1, when K<1 MW are subjected to diffraction loss, and ground reflections. When K>1 MW are subjected to elevated layer reflection [2],[5],[7][8].

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E. *Fresnel Zone clearance:*

Radio waves spread out as they propagate. Fresnel zone is a three-dimensional ellipsoid between the transmitter and receiver. Radius of the Fresnel Zone depends on frequency of operation and hop length. As hop length increase Fresnel radius also increases and will be maximum at mid-point of the path. While estimating the tower heights for the Long haul hops 100% clearance to be given for first Fresnel zone radiusin addition to earth bulge clearance.

Fresnel zone diameter is given by $F1=17.3\sqrt{(d1d2)/fd}$……….eq.(2)

Where d1 is the distance from the transmitter in KMs and d2 is the distance from the receiver in KM's and d is the hop distance in KMsand f is the frequency in GHz.[5]

F. *Radio Threshold:*

Radio threshold is the minimum signal level at the input of the radio receiver to produce a BER of $1x10^{-3}$or $1x10^{-6}$ currently most of the designers consider $1x10^{-6}$ as the threshold

G. Estimation of received signal level:

RSL= Pt - Lc + Gtx - Lo + Grx - FSL…………………………...eq. (3)

Where Pt = Transmitter power output at the Antenna input
Lc = Feeder cable Loss
Gtx = Transmit Antenna gain
Lo = other losses (siting losses etc)
Grx = Receive Antenna gain
FSL = Free space path loss

FSL= 92.4+ 20Logd +20logf……………………………………eq. (4)

Where d = hop length in Kms
f= frequency in GHz

H. *Link feasibility*

Is to verify whether the calculated Receive Signal Level (RSL) at Receiver is greater than the Threshold level of the radio.

MW link is theoretically feasible if

RSL > or = Rx …………………………………………………...eq. (5)

Where Rx= radio threshold

I. Fade margin

As indicated in section I. and section II.B and II.D, performance MW links is affected by multipath fading and rain attenuation. Some times RSL may go below Rx Threshold. During such situations MW link may be subjected to frequent outages. To compensate for this RSL reduction during fade situation additional margin is built in, to ensure that MW link is available for all the 365 days of the year. This additional margin is known as fade margin [8]

Fade margin = RSL – Rx(threshold)………………………………………eq. (6)

J. *MW link performance and availability*

Performance is a short term specification typically for a month, whereas Availability is long term and is for one year period. ITU-T(G826) has specified performances specifications for PDH and SDH radios separately in terms of Errored seconds, severely erroded seconds and Block errors. ITUR(1703) has specified annual availability figures. In addition performance and availability figures are bifurcated for short haul and Long-haul links [1],[3].

K. *Availability calculations*

Different methods are followed for availability calculations. ITUR 530 methods are popular. These methods estimate the probability of Multipath fade and rain fade depth (dB) exceeding the designed Fade margin either by 1% or 0.1%or 0.01% of the time (over one year), Factors like terrain roughness, Geoclimatic factor, path length, path inclination, frequency, fade margin are considered for availability calculations, The fade probability P that the fade depth F dB exceeded in the worst month isindicated below

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III. $P=K.d^{3.3}.f^{0.93}.(1+\epsilon_p)^{-1.1}.\theta^{-1.2}.10^{-F/10}$……………… eq. (7)

K= Geo climatic factor, d= path length in KMs,f=frequency in GHz,
ϵp =Path inclination in mili radians,
θ= Average grazing angle in mili radians, Corresponding to a 4/3 earth radius factor,
F=effective fade margin in dB, K is estimated from the percentage of time PL that the average refractivity Gradient in the lowest 100m of the atmosphere is less than-100N units/Km,[1],[4],[5]

III. PROPOSED WORK- PRACTICAL DESIGN OF HIGH CAPACITY MICROWAVE INTERCITY LINK

A. *Design steps:*

following paragraphs indicate different steps to be followed to design a high capacity mw link between two cities. for the test case two towns kudchi and rabkavi banahatti falling in in north karnataka and which are 41.2 kms apart by road are selected. the los distance between the two sites is32.9kms. fig.1 and fig.2 indicate the sites road distance and the los distance. nw diagram of the sites is created in the pathloss tool (mw link planning tool used for the test case). elevation of kudchi above msl=540m and elevation of rabkavi banahatti = 537m.

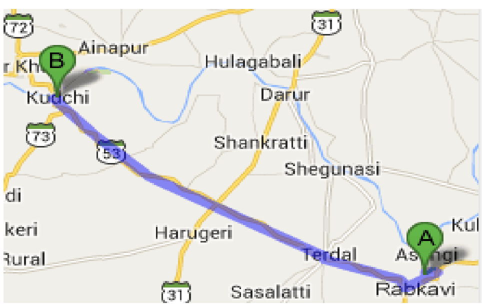

Fig.2Kudchi-Rabkavibanahatti- sites

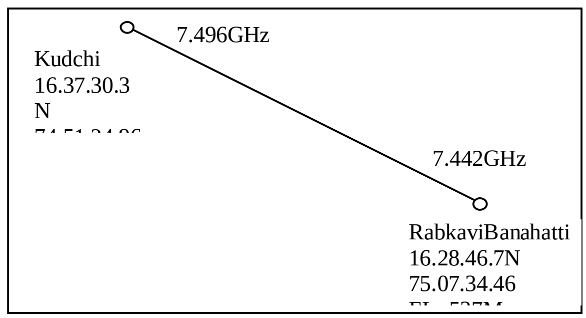

Fig.3Kudchi -Rabkavibanahatti- NW diagram

B. *Path Profile:*

LOS feasibility between the two sites which are to be connected by MW is to be verified. Either standard1:50,000 ordinance maps with 30m elevation contours or Terrain software with30m elevation contours can be used. In traditional method latitudes and Longitudes of the two sites are marked on the Map. If the sites coordinates does not fall on a single MAP, multiple Maps may be used. A line is drawn between the two sites and elevation figures at different locations, crossing the elevation path to be read and recorded, these values is entered to the MW link engineering Pathloss tool. Alternatively terrain profile can generated from the tool itself using inbuilt terrain software for that particular region,Fig.3 indicates the path profile. It can be seen that path profile is normal without major obstructions between the sites [5].

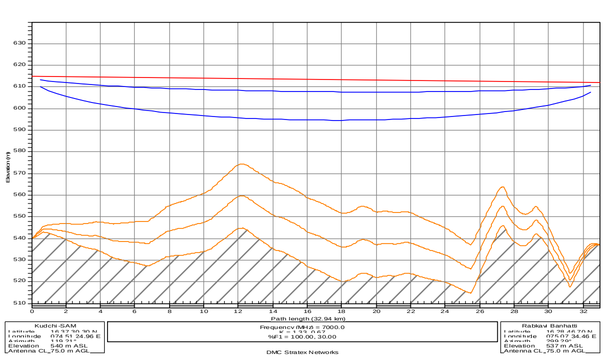

Fig.4Path profile of Kudchi- Rabkavi banahatti hop

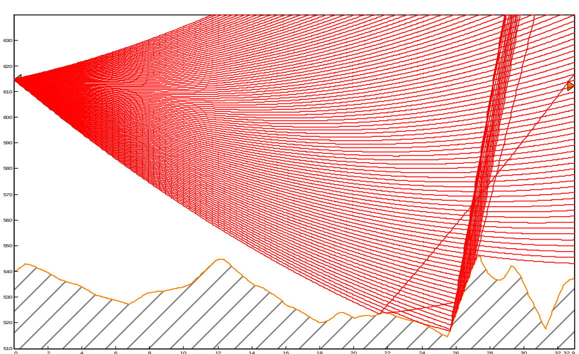

Fig.5 Multipath Analysis- Kudchi- Rabkavi banahatti hop

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C. *Route Walk*

Route walk is a must to ascertain the elevation contours recorded using ordinance maps or Elevation software used to generate the path profile, and to verify for the presence of any obstructions falling on the LOS path including natural obstructions like trees and Manmade obstructions like buildings and water tanks etc

D. *Tower heights estimation:*

Path profile is revisited after the route walk. Elevation figures are modified wherever required based on route walk data. Tower heights can be estimated from the path profile, by entering appropriate tower heights in to the tool so as to get 100% clearance for first Fresnel zone and 60% clearance for the second Fresnel zone. A minimum of 10M clearance to be provided for the 2nd Fresnel zone radius for the two earth bulge factor for K=1.33 and K=0.6.Additonal 10m clearance is provided for future tree growth. Sufficient clearance is provided for K=0.6 to avoid occurrence of multipath reflections due to inclement weather. It can be seen minimum of 65M tower height are required at both the sites. However to achieve sufficient clearance 75M towers heights are required [5][8].

E. *Multipath Analysis:*

Multipath is one of the serious issues of Long hop length paths. RSL varies due to change in weather conditions. Fade depths may vary from few dB's 40dB's . Changes in the weather conditions may occur either daily or seasonally. MW path is subjected to multipath reflections when path is crossing over smooth sand, paddy field or when the microwave path is diffracted (K<1), or due to elevated layers. As a thumb rule sufficient clearance for the path to be given by increasing the tower heights to avoid reflections due to diffraction. Tower heights and Link budget to be finalized after Multipath Tower heights at both the sites may be varied to minimize the multipath effect. In case it is found not possible to minimize multipath by varying antenna heights, Space diversity of frequency diversity to be used [6][8].

F. *Link Budget*

Link budget is the estimation of fade margin to be built in the link to take care of Multipath fade and rain fade, to achieve an annual availability of better than 99.99 % and to estimate RSL, Antenna sizes required for a particular type of radio. Long hop length links are engineered in 6/7/8 GHz band. These band of frequencies are not affected by rain, hence link budget calculations should cater for multipath fading. Threshold level of SDH radios is around -68 dBm. At least of 35 dB fade margin to be built for high capacity long hop length MW links. Table.I indicates link budget for the test case [5].

TABLE. I *Link Budget*

Site Name	**Coordinates**	**Elevation - M**	**Hop length KM**	**Azimuth degrees**	**Tower Ht. M**	**Antenna dia in M**	**RSL in dBm**	**Radio type**	**Frequency in Ghz**	**Polarization**
From Kudchi	*16.37.30.3N 74.51.24.96 E*	*540*	*32.9*	*119*	*75*	*3.0*	*-25.6*	*SDH*	*7.496*	*V*
To Rabkavi	*16.28.46.7N 75.07.34.46 E*	*537*		*299*	*75*	*3.0*	*-25.6*	*SDH*	*7.442*	*V*

IV. CONCLUSIONS

Long hop length paths are severely affected by atmospheric variations and multipath fading effects. MW path to be analysed for multipath effect and Antenna heights are to be varied suitably to minimise the multipath effect and to shift the reflection point, or else Link will be subjected to frequent outages. Availability figures should be better than 99.99%.Towers should be designed with minimum deflection specifications, to with stand the weight of the large antennas and the wind load, to avoid link outages during heavy wind and rain.

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