# Planning, Designing and Performance Evaluation of Micro Wave Link Case Study from Wegeda to NefasMewucha

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**Abstract.** The Microwave link is an alternative link for fiber optics or for the area which is difficult to practically implement fiber optics and satellite link access. It has different properties like line of sight, environmental constraints, including rain fade and many obstacle issues such as hills, buildings and trees. In Ethiopia, Amhara region, South Gondar, currently the hill station in between Wegeda Amanuel areas, microwave link severely affected and equipment failure due to the environmental interferences. Because of interruption of this link, most of the times stop the connection of this area. Due to the above limitation of the rural access to this area, this paper is specially intended to provide and fulfill the needs by planning and designing microwave link between NefasMewucha to Wegeda. The traffic from and to Wegeda is likely to increase in future as it is one of the important potential area in Amhara region. Hence, it needs reliable and efficient alternate communication link. In overall, this paper deals the site survey, system margins, frequency planning, power budget calculation and performance evaluation activities and the results are simulated using Global mapper 12.

**Keywords:** Path clearance · Signal Radiation Loss · System Margin · Power budget · Link reliability

## 1 Introduction

Microwave link is very important in the Ethiopia Amhara region because most of the geographical areas are not suitable for wired communications systems. Wegeda is one of the most inconvenient areas for copper wire and optical fiber link, but these areas are highly productive and it should have an uninterrupted telecommunication network to access these products and increase the development. An alternative link has required to connect Wegeda to other parts of Amhara region and whole country. Preferably, micro wave link is a choice to achieve this objective in appropriate way for the cost effective, more convenient for the proposed link access better than optical link [7].


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The following Fig. 1 illustrates the flow chart approach for the proposed microwave link system and its design process. Mainly, the proposed link focus on the path performance for stage by stages per the system design process [2].

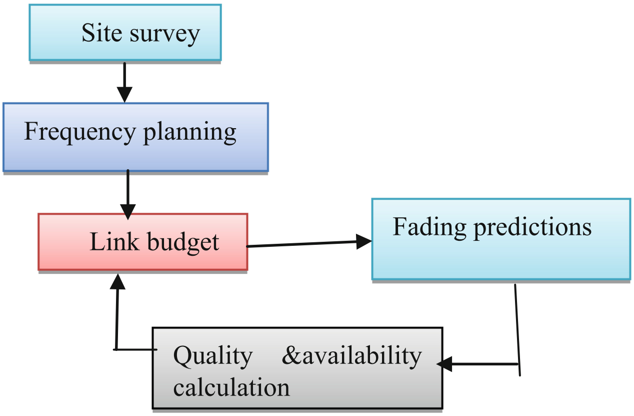


**Fig. 1.** System design process flow chart

## 2 Site Planning and Selection

The two sites of proposed link are, one is NefasMewucha and the other is Wegeda. From these sites, most of the real time data are collected by pilot surveying approach. These data are helped to know the path clearance, the coordinates of the sites, distance between path link, antenna height and the location and height of obstacles [3].

### 2.1 Path Wegeda to NefasMewucha

Figure 2 shows a geographical map of the two proposed terminals (Wegeda to NefasMewucha).

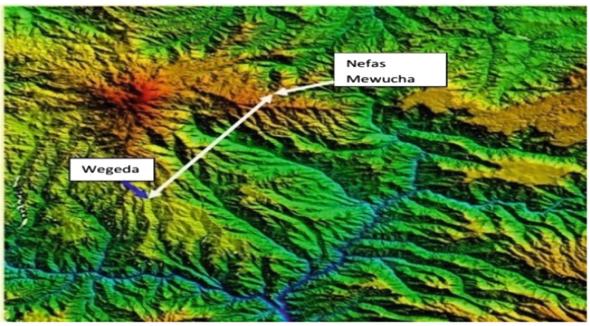


**Fig. 2.** Map of area of interest of the link

The proposed link is from Wegeda to NefasMewucha and its coordinate is measured at the presently existing tower of the two sites by using Global Positioning System (GPS) receivers and possible hop distance is determined by Global mapper 12 software by using these coordinates. Table 1 given below shows the coordinates and possible hop distance of the proposed link.

**Table 1.** Co-ordinates and hop distance of Wegeda and NefasMewucha

| Path profile | Radio terminals sites | |
|---|---|---|
| | Wegeda | NefasMewucha |
| Latitude | 11°23′50.0580″N | 11°44′505″N |
| Longitude | 38°14′18.173″E | 38°28′665″E |
| Elevation | 2560.84 m | 3010 m |
| Maximum Hop length | 45.1 km from NefasMewucha | 45.1 km from Wegeda |

Note: the hop length from the above Table 1 is line of sight length not road distance.

Based on the above data, path profile between two sites, the maximum hop length, elevation of the two sites and the maximum height of obstacles are obtained and shown in Fig. 3.

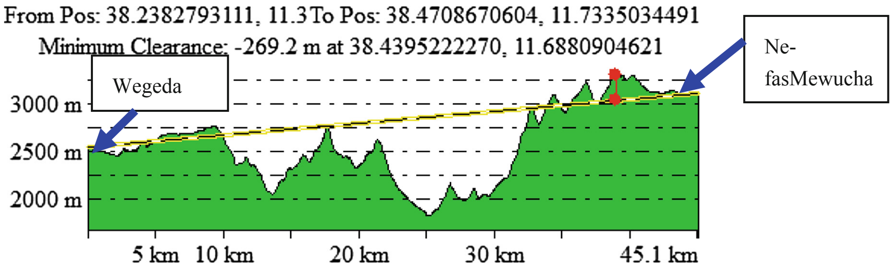


**Fig. 3.** Path distance from Wegeda to NefasMewucha

As shown in Fig. 3. It is observed that the link is not a clear line of sight. So an alternative link is required.

## 2.2 Recommended Hop Link: Wegeda to Guna and Guna to NefasMewucha

The two recommended hop links are from Wegeda to Guna and from Guna to Nefas-Mewucha with repeater at Guna. The map shown in Fig. 4 illustrates the two alternative links.

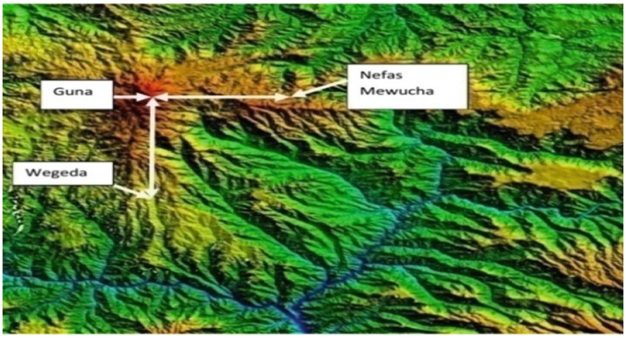


**Fig. 4.** Illustrate the hop from Wegeda to Guna and Guna to NefasMewucha

Coordinates of the two hops such as latitude, longitude and elevation are measured using GPS receivers at the existing towers (Table 2).

**Table 2.** Co-ordinates of sites and their path length

| Path profile | Link sites | | |
|---|---|---|---|
| | Wegeda | NefasMewucha | Guna |
| Latitude | 11°23′50.0580″N | 11°44′505″N | 11°42′39″N |
| Longitude | 38°14′18.173″E | 38°28′665″E | 38°14′31.9605″E |
| Elevation | 2560.84 m | 3010 m | 4122 m |
| Maximum hop length | 35.0 km from Guna | 25.5 km from Guna | 35.0 km to Wegeda & 25.5 km from NefasMewucha |

Note:- The hop distance in the above table is line of sight distance.

The path profile of the two alternative links, from Wegeda to Guna and Guna to NefasMewucha are shown in Figs. 5 and 6 below. The path profile of the hop from Wegeda to Guna and Guna to NefasMewucha needs minimum 28.8 m and 21.4 m height antennas respectively for line of sight.

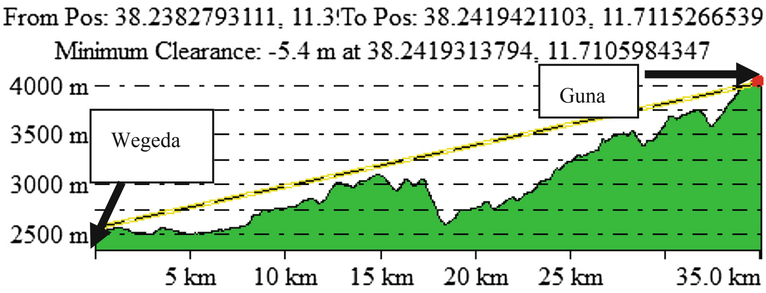


**Fig. 5.** Path profile from Wegeda-Guna

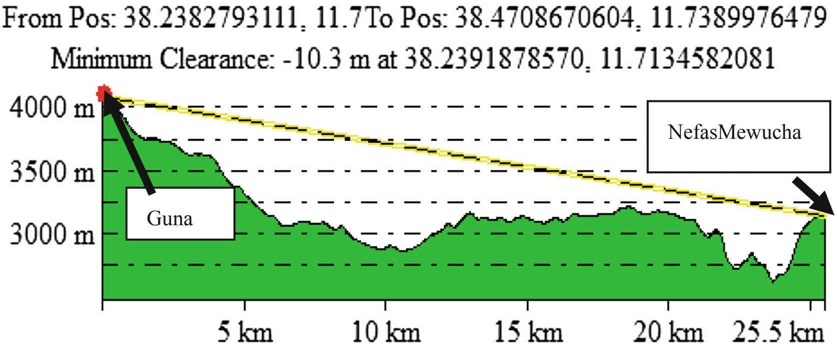


**Fig. 6.** Path link length from Guna to NefasMewucha

## 2.3 Frequency Planning

The operating frequency bands of existing link at the Guna station in the direction of the proposed link is 8 GHz. So, that the frequency to be selected should be different from this band. In the design link 7 GHz frequency band is used for both transmitter and receiver frequency for each hop as per Table 3 shown below

**Table 3.** Frequency arrangement

| Station | Unit | Tx module | Rx module | LO | IF (Tx/Rx) | T/R (Duplex) |
|---|---|---|---|---|---|---|
| Guna | MHz | 7550 | 7850 | 5550 | 2000/2161 | 161 MHz |
| NefasMewucha to/from Guna | MHz | 7850 | 7550 | | 2161/2000 | |
| Guna to/from Wegeda | MHz | 7125 | 7425 | 5125 | 2000/2161 | 161/154 MHz |
| Wegeda | MHz | 7425 | 7125 | | 2161/2000 | |

## 3 Use of Repeaters

As shown in Fig. 3 below, it is already seen that there is no possibility of establishing the direct microwave link between the stations Wegeda to NefasMewucha due to LOS obstruction. Hence a repeater station in Guna is suggested in between [11].

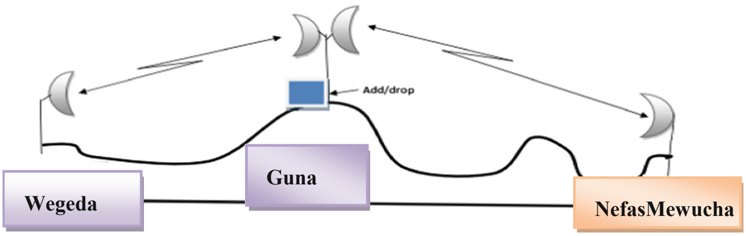


**Fig. 7.** Repeaters between Wegeda and NefasMewucha

At Guna station adds/drops of data, voice and videos are done by using ADM equipment.

## 4 First Fresnel Zone (FFZ)

After getting a feasible link, the next step in the microwave link design is calculating the (FFZ) radius, in order to know at least 60% of the FFZ free from any type of obstruction in the hop [6].

It depends on the hope length and the operating frequency [1]. For no obstructions between two sites, the maximum first Fresnel zone radius is calculated using the following formula [6].

$$F = 8,657\sqrt{l/f} \tag{1}$$

Where

F = first Fresnel zone
l = the maximum hop length in meter
f = operating frequency of the link

### 4.1 FFZ –Wegeda to Guna

The maximum 60% FFZ of this path is calculated using Eq. (1) with,

l = Hop length from Wegeda to Guna in meter = 35 km = 35000 m
f = operating frequency of link = 7.125 GHz

$$F = 8,657\sqrt{35000/7.125 * 10^9} = 19.187$$

### 4.2 FFZ– Guna to NefasMewucha

The 60% radius of the FFZ for the above link is calculated using Eq. (1) with,

l = Hop length from Guna to NefasMewucha 25.5 km = 25500 m
f = operating frequency of path = 7.55 GHz

$$F = 8,657\sqrt{}25500/7.55 * 10^{9} = 15.9\,\text{m}$$

## 5 Antenna Height Calculation

Antenna height of the microwave link is calculated based on the Rec. ITU-R P.530-14 [10]. For the first hop antenna height, ($A_h$) = 1.0 * $F_1$ = 1 * 19.187 m = 19.187 m, we must consider the height of trees and growth of vegetables 12 m and 3 m respectively. Where $F_1$ is First Fresnel Zone radius, so the antenna height, ($A_h$) = 19.187 m + 12 m + 3 m = 34.187 m (this is the minimum antenna height for the first hop).

Similarly, the same procedure can be repeated for the second hop.

Antenna height, ($A_h$) = 1.0 * $F_1$ + 12 m + 3 m = 15.9 m + 12 m + 3 m = 30.9 m (this is the minimum antenna height for the second hop). In the two hops, the antenna should not be mounted less than the calculated height.

In our design, the antennas can be mounted at 40 m and 35 m for the first hop and the second hop on the existing tower heights respectively to have more clearance.

The first and second hop path profiles with the recommended antenna heights have 34.6 m and 24.7 m give clearance from any obstacle and they are shown in Figs. 8 and 9 respectively. These indicate the feasible path of the two hops.

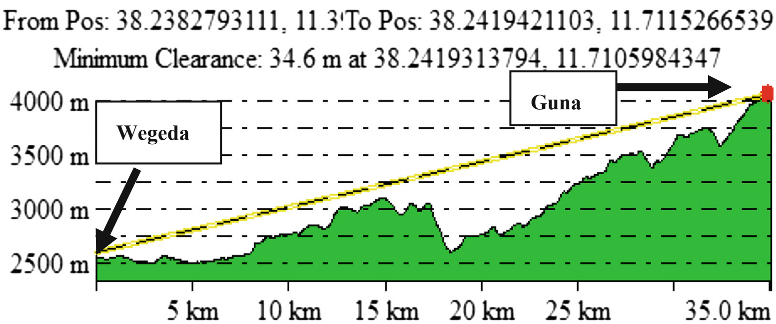


**Fig. 8.** Path clearance from Wegeda to Guna with 40 m antenna height

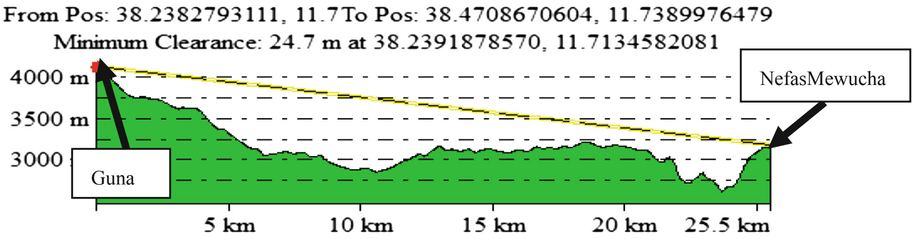


**Fig. 9.** Path from Guna to NefasMewucha with 35 m antenna height

## 6 Micro Wave Link Path Analysis

Microwave link path analysis is carried out to dimension the link and it is a calculation involving the gain and loss factors associated with the antennas, transmitters, transmission lines and propagation environment [2].

### 6.1 Signal Radiation Losses (SRL)

Signal radiation loss is the degradation of transmitting signals, when it propagates through a free space. This loss depends on the length of links and the operating frequency of path [4].

If the frequency and the distance are expressed in terms of Kilometer and Giga Hertz, the signal radiation loss is given by the following equation [6, 8].

$$L_{SRL} = 92.45 + 20\log(f) + 20\log(d)\ [\mathrm{dB}] \tag{2}$$

Where

f = frequency (GHz)
d = distance of hop between transmitter and receiver (Km)

### 6.2 Power Received ($P_r$)

The receive power is the amount of power reached at the receiver unit after the transmitted power pass through a free space [5]. To assure the link feasibility the received power magnitude must be greater than or equal to the Receiver sensitivity threshold. $P_r$ can calculate using the following formula [8].

$$P_r = P_t - L_{ctx} + G_{atx} - L_{crx} + G_{arx} - SRL - R_t\ [\mathrm{dBm}] \tag{3}$$

Where

$P_r$ = Power received
$P_t$ = Output power of the transmitter (dBm)
$L_{ctx,}$ = Connectors, branching Loss (cable unit) b/n Transmitter and Transmitter antenna (dB)
$L_{crx}$ = Connectors, branching Loss (cable unit) b/n Receiver and Receiver antenna (dB)
$G_{atx}$ = Gain of transmitter antenna (dBi)
$G_{arx}$ = Gain of receiver antenna (dBi)
SRL = Signal Radiation Loss (dB)
$R_t$ = Rain attenuation (dB)
$P_r \geq R_s$ (receiver sensitivity threshold)

### 6.3 Rain Attenuation Calculation for the First Hop (Wegeda to Guna)

The rain data were taken from National Metrology Agency Bahir Dar branch which is collected from NefasMewucha, Simada (Wegeda) and Gassay rain fall sites.

The rain attenuation calculations are calculated based on ITU-R Model of Rain Attenuation because the rain attenuation is minimum in this model when compare to other methods. It is calculated by using the following steps [9].

**Step 1:** Obtain the rain rate R0.01 exceeded in 0.01% of the time (with an integration of 1 min) [9]. The maximum rain rate at the two sites are taken from the collected data. But in Guna there is no rainfall station, we use the rainfall data from Gassay station, which is near to Guna and it has almost the same rain data. The maximum rain rate at Wegeda and Gassay record in July 2013 and mar 2014, and the values are 444.9 mm/h and 719.6 mm/h respectively. The average rain ratings are used.

$$\begin{aligned} \text{Average rain rate} &= (444.9\,\text{mm/h} + 719.6\,\text{mm/h})/2 \\ &= 582.25\,\text{mm/h} \\ R_{0.01} &= 582.25\,\text{mm}/60\,\text{min} = 9.7\,\text{mm/min} \end{aligned}$$

**Step 2:** Compute the specific attenuation, γ (dB/km) for 7 GHz frequency band, vertical polarization and the above rain rate. It can be expressed as follows [9].

$$\gamma = KR^{\alpha} \tag{4}$$

Where

$\gamma$ = rain rate at p% of probability
$K$, $\alpha$ = functions of frequency, f (GHz) in the range 1 to 1000 GHz.

The specific attenuation is computed by using k = 0.00265 and α = 1.312, these values are tabulated values by different publications for 7 GHz frequency. Therefore, specific attenuation is calculated by using Eq. (4).

$$\gamma = KR^{\alpha} = 0.00265 * 9.7^{1.312} = 0.0522\,\mathrm{dB/km}$$

**Step 3:** Compute the effective path length, $d_{eff}$, of the link by multiplying the actual path length (1) by a distance factor(r). Before computing effective path length, distance factor is given by [9].

$$r = 1/1 + 1/d_0 \tag{5}$$

Where

r = distance factor
l = path length

Where, for $R_{0.001} \leq 100$ mm/h [10].

$$d_0 = 35e_{0.01}^{-0.015R} \tag{6}$$

With actual path length of 35 km and $d_0$ is calculated by Eq. (6)
But in our design 0.01 R ≥ 100 mm/h, we use the value 100 mm/h in place of 0.01*R*.

$$d_0 = 35e^{-0.015*100} = 3.448\,\mathrm{km}$$

Therefore, distance factor and effective distance become.

$$\text{And} \quad d_{eff} = 35\,\mathrm{km} * 0.0897 = 3.1395\,\mathrm{km}$$

**Step 4:** An estimate of the path attenuation exceeded in 0.01% of the time is given by [9]

$$A_{0.01} = \gamma d_{eff} = \gamma l.r\,(\mathrm{dB}) \tag{7}$$

Where

l = path length
r = reduction factor

By using the values of effective distance and specific attenuation from the above analysis the estimated path attenuation exceeded 0.01% becomes

$$A_{0.01} = 0.0522 * 3.1395 = 0.164\,\mathrm{dB}$$

### 6.4 Rain Attenuation Calculation for the Second Hop (Guna to NefasMewucha)

The rain attenuation calculations are calculated based on ITU-R Model of Rain Attenuation because the rain attenuation is minimum in this model when compare to other methods [9]. It is calculated by using the following steps.

**Step 1:** The rain rate R0.01 exceeded in 0.01% of the time (with an integration of 1 min) [9]. The data were collected by the national metrology agency, Bahir Dar branch. We take the maximum rain rate at the two sites from the collected data. But at Guna there is no rainfall station, we use the rainfall data from Gassay station which is near to Guna. The maximum rain rate at Guna and NefasMewucha are recorded in March 2014 and July 1998, and the values are 719.6 mm/h and 510.0 mm/h respectively. The average rain ratings are used.

$$\begin{aligned} \text{Average rain rate} &= (510.0\,\text{mm/h} \ + \ 719.6\,\text{mm/h})/2 \\ &= 614.8\,\text{mm/h} \\ R_{0.01} &= 614.8\,\text{mm}/60\,\text{min} = 10.25\,\text{mm/min} \end{aligned}$$

**Step 2:** Computation of the specific attenuation, $\gamma$ (dB/km) for 7 GHz frequency band, vertical polarization and the above rain rate. The specific attenuation is computed by using $k = 0.00265$ and $\alpha = 1.312$, these values are tabulated values by different publications for 7 GHz frequency. The calculation is done by using Eq. (4) as follow.

$$\gamma = KR^{\alpha} = 0.00265 * 10.25^{1.312} = 0.056\,\text{dB/km}$$

**Step 3:** Computation of the effective path length, $d_{eff}$, of the link by multiplying the actual path length (l) by a distance factor *r*. Before computing effective path length, we must calculate the distance factor by using Eq. (5) with actual path length of 25.5 km and $d_0$ is calculated by Eqs. (6).

But In our design 0.01 R $\geq$ 100 mm/h, we use the value 100 mm/h in place of 0.01*R*.

$$d_0 = 35e^{-0.015*100} = 3.448\,\text{km}$$

Therefore, distance factor and effective distance become.

$$\begin{aligned} r &= 1/(1 + 25.5\,\text{km}/3.448\,\text{km}) = 1/8.3956 = 0.119 \\ \text{And} \quad d_{eff} &= 25.5\,\text{km} * 0.119 = 3.037\,\text{km} \end{aligned}$$

**Step 4**: An estimate of the path attenuation exceeded in 0.01% of the time is calculated by using Eq. (7)

$$A_{0.01} = 0.056 * 3.037 = 0.17\,\text{dB}$$

The rain attenuation of the first hop and the second hop are 0.164 dB and 0.17 dB respectively. This result shows the rain attenuation is directly proportional to the rain rate because the rain rate in the second hop is greater than the first hop.

### 6.5 System Margin (SM)

System margin is an essential parameter in microwave link path which is to evaluate the performance of the link to be established and it can be expressed as

$$SM = P_r - R_{th} \tag{8}$$

Where

$SM$ = System margin
$P_r$ = Received Signal Level
$R_{th}$ = Receiver threshold

## 7 Power Budget of the Proposed Link

Before establishing the path of the proposed link we should determine the equipment's used at the transmitter and the receiver site and select that equipment's with appropriate ratings to have a reliable system [2].

The specification of the equipment's used at the transmitter and receiver site is shown in Table 4 below.

**Table 4.** Rating of equipment used in transmitters and receivers site

| Frequency bands (GHz) | | 7 |
|---|---|---|
| Full-duplex | | FDD |
| Operating frequency | | 7125 MHz to 7900 MHz |
| Standby mode configuration | | 1 + 0 or 1 + 1 |
| Power supply (V) | | DC: −48 V (+24 V), 10% |
| RF output power (dBm) | | 27 |
| Receiver threshold (dBm) | | −84 |
| Antenna gain (dBi) medium (0.9 m diameter) | | 34.8 |
| Type of cable | Operating frequency | Loss in dB per 100 feet |
| LMR-900 | 7 GHz | 2.9 |

### 7.1 Power Budget from Wegeda to Guna

In order to calculate the Power budget, we use the specifications of the equipment given in Table 4.

**Signal Radiation Loss *(SRL)***
Signal Radiation Loss in free space *is* calculated using Eq. (2) with f = frequency (GHz) = 7.125 and d = distance of the hop between *Wegeda to Guna* (Km) = 35

$$
\begin{aligned}
L_{SRL} &= 92.45 + 20\log(7.125) + 20\log(35)\ [\mathrm{dB}] \\
&= 92.45 + 17.055 + 30.88 = 140.386\ \mathrm{dB}
\end{aligned}
$$

**Power Received $P_r$**
Received power at the receiver side can be calculated using Eq. (4) with $P_t$ = output power of the transmitter (dBm) = 27 and Lctx, = Loss (cable, connectors, branching unit at Tx) = 5.766 dB + 0.025 dB = 5.79 dB, because the cable length at the transmitter side is 60 m, it has 5.766 dB loss and 0.025 dB is connector loss.

$L_{crx}$ = Loss (cable, connectors, branching unit at Rx) 5.766 dB + 0.025 dB = 5.79 dB, because the cable length at the receiver side is 60 m, it has 5.766 dB loss and 0.025 dB is connector loss between transmitter/receiver and antenna.

$G_{atx}$ = Gain of transmitter antenna (dBi) = 34.8
$G_{atx}$ = Gain of transmitter antenna (dBi) = 34.8
$G_{arx}$ = Gain of receiver antenna (dBi) = 34.8
$L_{SRL}$ = Signal Radiation Loss (dB) = 140.386
$R_t$ = Rain attenuation (dB) = 0.164

$$
\begin{aligned}
P_r &= 27\ \mathrm{dBm} + 34.8\ \mathrm{dBi} - 5.79\ \mathrm{dB} + 34.8\ \mathrm{dBi} - 5.79\ \mathrm{dB} - 140.386\ \mathrm{dB} - 0.164\ \mathrm{dB} \\
&= -\ 55.53\ \mathrm{dBm}
\end{aligned}
$$

**System Margin (SM)**
The system margin of the above path can be calculated as follows using Eq. (8).

With $P_r$ = power Received = −55.53 dBm and $R_{th}$ = Receiver threshold = −84 dBm

$$
\begin{aligned}
SM &= P_r - R_{th} \\
&= -\ 55.53\ \mathrm{dBm} - (-84\ \mathrm{dBm}) = 28.47\ \mathrm{dB}
\end{aligned}
$$

## 7.2 Link Budget from Guna to NefasMewucha

In order to calculate the power budget, we use the specifications of the equipment given in Table 4.

**Signal Radiation Loss (SRL)**
Signal Radiation Loss in free space *is* calculated using Eq. (3) with f = frequency (GHz) = 7.55 and d = distance of the hop between Guna to NefasMewucha (Km) = 25.5

$$
\begin{aligned}
L_{SRL} &= 92.45 + 20\log(7.55) + 20\log(25.5)\ [\mathrm{dB}] \\
&= 92.45 + 17.559 + 28.13 = 138.14\,\mathrm{dB}
\end{aligned}
$$

**Power Received ($P_r$)**
Received power at the receiver side in the second hop can be calculated using Eq. (4) with $P_t$ = output power of the transmitter (dBm) = 27, $L_{ctx}$, = Loss (cable, connectors, 55 m, it has 5.23 dB loss and 0.025 dB is connector loss between transmitter/receiver and antenna (dB) = 5.23 dB + 0.025 dB = 5.255 dB, $L_{crx}$ = Loss (cable, connectors, branching unit at Rx) 5.23 dB + 0.025 dB = 5.255 dB, because the cable length at the transmitter side is 55 m, it has 5.23 dB loss and 0.025 dB is connector loss between transmitter/receiver and antenna, $G_{atx}$ = gain of the transmitter antenna (dBi) = 34.8, $G_{arx}$ = gain of receiver antenna (dBi) = 34.8, $L_{SRL}$ = Signal Radiation Loss s (dB) = 138.14 and $R_t$ = rain attenuation (dB) = 0.17 dB.

$$
\begin{aligned}
P_r &= 27\,\mathrm{dBm} + 34.8\,\mathrm{dBi} - 5.255\,\mathrm{dB} + 34.8\,\mathrm{dBi} - 5.255\,\mathrm{dB} - 138.14\,\mathrm{dB} - 0.17\,\mathrm{dB} \\
&= -52.22\,\mathrm{dBm}
\end{aligned}
$$

**System Margin**
The system margin of the above path can be calculated as follows using Eq. (8) with $P_r$ = power Received = −52.22 dBm and $R_{th}$ = Receiver threshold = −84 dB.

$$
\begin{aligned}
SM &= P_r - R_{th} \\
&= -52.22\,\mathrm{dBm} - (-84\,\mathrm{dBm}) = 31.78\,\mathrm{dB}
\end{aligned}
$$

Note: in the power budget analysis of the above two hops, Wegeda to Guna has system margin of 28.47 dB and the second Guna to NefasMewucha has 31.78 dB. These results are greater than 10 dB (threshold value) which shows the link has the ability to provide guaranteed quality of service.

## 8 Link Availability

The path availability also called link reliability is the percentage of time that the received signal is above the required threshold, $P_{req}$. It is sometimes expressed as the expected minutes of outage per year and the percentage of time represents the outage time for a given link budget [8]. The path availability is function of the radio frequency, diversity, fade margin, path length, and local climate. The International Telecommunication Union publishes reports with empirical models of required fade margin for different parts of the world [10].

The percentage of time ($P_w$) that fades depth (A) (dB) is exceeded in the average worst month is calculated by using the following equation [10].

$$P_w = k * l^{3.6} * f^{0.89}\left(1 + |\varepsilon_p|\right)^{-1.4} * 10^{-A/10} \quad (9)$$

Where

k = geoclimatic factor
l = path length in km
f = frequency in GHz
$\varepsilon_P$ = path slope
A = fade margin [dB]

The path inclination $|\varepsilon_p|$ (mrad) of the link is calculated from the antenna heights of the transmitter and receiver (above sea level or some other reference height) and it is calculated as follows [10],

$$\varepsilon_p = (h_A - h_B)/l \quad (10)$$

Where

$h_A$ = antenna height + ground elevation at the transmitter in m
$h_B$ = antenna height + ground elevation at the receiver in m
l = path length in Km

Another parameter that determines the percentage of the time average worst month is geoclimatic (k) factor.

It can be calculated using

$$K = 10^{-(6.5 - Clat - Clon)} P_L^{1.5} \quad (11)$$

The above equation is because of that the proposed link is Overland links for which the lower of the transmitting and receiving antennas is less than 70 m above mean sea level.

ITU recommendation calculations for K, there are four K categories, two of which are for overland inks and two for over-water links. K can be estimated from the contour maps given in Figures of ITU-R PN.453-4, from Figs. 7, 8, and 9. For the percentage of time $P_L$ that the average refractivity gradient in the lowest 100 m of the atmosphere is less than 100 N-units per km [8].

The value of $P_L$ is determined by using figures of ITU-R PN.453-4. From these figures the value of $P_L$ is determined to be 5, 20, 10 and 1 for the months of November, August, May and February respectively and we take the highest value. Hence 20 is used as $P_L$ value, and 0 (dB), and 0.3 (dB) are taken as the value of $C_{Lat}$ and $C_{Lon}$ respectively.

By using Eq. (11).

$$K = 10^{-(6.5-0-0.3)}20^{1.5} = 5.64 * 10^{-5}$$

### 8.1 Link Availability from Wegeda to Guna

After we determine geoclimatic (k) factors, path inclination will be calculated by using Eq. (10) with $h_A = 2610.08$ m, $l = 35$ km and $h_B = 4162$ m

$$\varepsilon_p = (2610.08 - 4162)\ \mathrm{m}/35 = -44.34$$

Hence, the percentage of time ($P_w$) can be calculated by using Eq. (9) with fade depth (A) = 28.47 dB

$$\begin{aligned} P_w &= 5.64 * 10^{-5} * 35^{3.6} * 7^{0.89}(1 + |-44.34|)^{-1..4} * 10^{-28.47710} \\ &= 77.45 * 10^{-5} = 0.0007745\% \end{aligned}$$

We can consider the above outage (unavailability) is due to equipment failure and propagation outage. The outage is expressed in terms of hour, minute and second. Let us consider a 1-year or 8760-h interval. A year has 525,600 min or 31,536,000 s. Then the annual expected outage of this link with unavailability of 0.0007745% is

$$\begin{aligned} &8760\,\mathrm{h} * 0.000007745 = 0.06784\,\mathrm{h} \\ &525,600\,\mathrm{min} * 0.000007745 = 4.070772\,\mathrm{min} \\ &31,536,000\,\mathrm{s} * 0.000007745 = 244.2463\,\mathrm{s} \end{aligned}$$

Therefore, unavailability occurs in this hop 0.06784 h, 4.070772 min or 244.24632 s annually.

The availability of this link is determined based on the outage of the worth month or time percentage and it can be calculated as follows.

$$\begin{aligned} \text{Link availability } (P_A)\,\% &= 100\% - P_W\% \\ &= 100\% - 0.0007745 \\ &= 99.9992255\% \end{aligned}$$

From the above unavailability and availability values we can say the link is reliable.

### 8.2 Link Availability from Guna to NefasMewucha

After we determine geoclimatic (k) factors, path inclination will be calculated. By using Eq. (10) with $h_A = 4157$ m, $l = 25.5$ km and $h_B = 3045$ m

$$\varepsilon_p = (4157\,\text{m} - 3045\,\text{m})/25.5 = 43.6$$

Hence, the percentage of time ($p_w$) can be calculated by using Eq. (9) with fade depth (A) = 31.78 dB

$$P_w = 5.64 * 10^{-5} * 25.5^{3.6} * 7^{0.89}(1 + |43.6|)^{-1..4} * 10^{-31.78/10} = 8.51 * 10^{-5} = 0.0000851\%$$

We can consider the above outage (unavailability) is due to equipment failure and propagation outage. The outage is expressed in terms of hour, minute and second. Let us consider a 1-year or 8760-h interval. A year has 525,600 min or 31,536,000 s. Then the annual expected outage of this link with unavailability of 0.0000851% is

$$8760\,\text{h} * 0.000000851 = 0.007455\,\text{h}$$
$$525,600\,\text{min} * 0.000000851 = 0.447286\,\text{min}$$
$$31,536,000\,\text{s} * 0.000000851 = 26.837\,\text{s}$$

Therefore, unavailability occurs in this hop 0.007455 h, 0.447286 min or 26.837 s annually.

The availability of this link is determined based on the outage of the worth month or time percentage and it can be calculated as follows.

$$\text{Link availability } (P_A)\,\% = 100\% - P_W\% = 100\% - 0.0000851\% = 99.9999149\%$$

From the above unavailability and availability values we can say the design system is reliable.

## 9 Conclusion

A direct microwave link between Wegeda to NefasMewucha was initially proposed because of the importance of Wegeda as one socioeconomic growth area in Amhara region. This direct link could not be designed due to Non-clear line of sight propagation. An alternative proposal consisting of two paths from Wegeda to Guna and from Guna to NefasMewucha has been considered and power budget, signal radiation loss, rain attenuation, system margin and reliability of the link are calculated and simulated. The results are found to be consistent with practice.

The link availability of the two hops was calculated based on ITU recommendations, which is 99.9992255% in the first hop and 99.9999149% in the second hop. The fade margin is 28.47 dB and 31.78 dB in the first and second hop respectively which are greater than the recommended fade margin, in other words as the outage or unavailability percentage is very small, the designed link is more reliable and quality of service will be established.

## References

1. Moreno, L.: Point-To-Point Radio Link Engineering (2001–2010)
2. Freeman, R.L.: Telecommunication System Engineering, 4th edn. Wiley, Hoboken (2004)
3. Balanis, C.A.: Antenna Theory, Analysis and Design, 3rd edn. Wiley, Hoboken (2005)
4. Young, M.F.: Planning a Microwave Radio Link (2002)
5. Garlington, T.: Microwave Line-of-Sight Transmission Engineering (2006)
6. Lehpamer, H.: Microwave Transmission Networks, Planning, Design and Deployment, 2nd edn, p. 106. McGraw-Hill Professional Engineering, New York (2004)
7. Rakib Al Mahmud, M.D., Khan, Z.S.: Analysis and planning microwave link to established efficient wireless communications. Blekinge Institute of Technology, September 2009
8. Ul Islam, M.R., et al.: Fade margins prediction for broadband fixed wireless access (BFWA) from measurements in tropics. Prog. Electromagn. Res. C **11**, 199–212 (2009)
9. Rec. ITU-R p.530-12: Propagation data and prediction methods required for the design of terrestrial line-of-sight systems. ITU, Geneva (2007)
10. ITU-R P.530-14: Propagation data and prediction methods required for the design of terrestrial line-of-sight systems. ITU, February 2012
11. Shaoying, C.:Digital Microwave Communication Principles V1.1. Huawei Technologies Co., Ltd., Shenzhen (2006)