Microwave Link Design between Jimma Main Campus and Agaro Branch

[1] Gemechu Dengia
[1]Leturer
Electrical and Computer Engineering Department,
Mizan-Tepi University,
P.O.Box:378, Tepi, Ethiopia

[2] Tofik Jemal
[2]Asst.Professor
Electrical and Computer Engineering Department,
Director for Postgraduate, Research and Publication,
JiT, Jimma University,
P.O.Box: 378, Jimma, Ethiopia.

[3] Sherwin Catolos
[3]Asst. professor
Electrical and Computer Engineering Department,
JiT, Jimma Universities,
P.O.Box: 378, Jimma, Ethiopia.

Abstract- **Microwaves are widely used for point to point communications, because their small wavelength allows conveniently-sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna. This allows nearby microwave equipment to use the same frequencies without interfering with each other.**

The aim of the thesis was to provide microwave radio link operating at microwave frequencies Jimma main and Agaro campuses, with the minimum objective reliability 99.999%. The designed link depends on Geo context-profiler for path profile analysis, Feko suite 5.5 for rectangular waveguide design, and link budget calculator. In the analysis there are parameters, which are significant in design of microwave link establishment: free space loss calculation, path profile analysis, fade margin, frequency planning, attenuation, rain fading predictions, reflection points calculation, , tower heights, Signal to Noise Ratio, Fresnel zone and link budget calculation. Fresnel zone clearance was considered at least at 60% of the first Fresnel zone.

Keywords: Sites selection, path profile analysis, Tower heights calculation, links budget, reflection point calculations, Systems (Transmitter, Receiver, RF repeater) products specifications, floured out waveguide designed

I. INTRODUCTION

Microwave communication is a cost-effective, can be rapidly installed, can cross complicated terrains, and efficient means to connect two or more wireless points together over a variety of terrains and space, where continuous runs of cable or fiber type transmission lines would not be practical or even possible.

The point to point microwave communication describes that transmission take place among two and provides dedicated point to point connectivity using directional antennas. In order to design point to point microwave link system, there are several technical choices that we considered for instances the microwave LOS link, the link budget, free space path loss on the link analysis.

A. Objectives

General objective

The aim of the thesis is to design point to point microwave link between Jimma main to Agaro branch campuses. The planning of a link must take into account cost, equipment availability, and Line of sight propagation availability. A Microwave link design methods; frequency planning, link budget, Rain fading, fade margin, outages and availability calculations.

Specific objective

- To analysis and find out; sites location, path profile analysis, tower heights, rain fading, and reflection point substantiation, clearance verification
- To plan the frequencies of the link depending on the hop length, rain fading
- To design horn antenna at 8.5GHz and 10.7GHz frequencies
- To list the equipments products specifications

B. Statement of the problem

Recently, the main focus of the computer center is shifted to the newly built campus-wide network of the university. From the conception to the implementation of the network infrastructure, the computer center has been eagerly participating in every activity. In fact, the network project was under the direct supervision of the computer center since the beginning.

C. Scope and limitations of the study

The links from main campus to site A of transmitting terminals, and site B to the receiving terminals were intended to connect by optical fiber. Repeater is located at Yebu 13.8 km from site A and 19 km distances from site B. The design is limited to by the geocontex-profiler for path profile analysis and determination of tower heights,Feko suite 5.5 for antenna feed design. The path round walk would be conducted to verify the line of sight clearance, assess the reflective potential surfaces; such as flat terrain, and water bodies and manmade obstructions.

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The type of soil would not be taken into consideration because of the inavailability of measuring instruments.

II. FUNDAMENTAL PARAMETERS IN MICROWAVE LINK

A. Line of Sight

For any point-to-point radio communication; the general setup requires Microwave antennas to be placed in a high position. It is very important to find out a visible path between sites before establishing the links. Figure 1 show a line of sight where one microwave antenna has a direct link to another antenna placed at far end.

Fig.1. Atypical line of sight microwave link

B. Free Space Loss

Signal power is diminished by geometric spreading of the wave front. The power of the signal is spread over a wave front, the area of which increases as the distance from the transmitter increases. Therefore, the power density diminishes. Free Space Loss is normally addressed when designing a link budget and the formula is given by;

$$FSL = 92.4 + 20 \log f + 20 \log D$$

Where f=frequency in GHz, D =distance is given in km, FSL=free-space loss dB

C. Fresnel Zone

The First Fresnel Zone is an ellipsoid-shaped volume around the line of sight path between transmitter and receiver. It defines a volume around the LOS that must be clear of any obstacle for the maximum power to reach the receiving antenna. For a line of sight; the main beam has to be clear at least 60% of the First Fresnel Zone was considered.

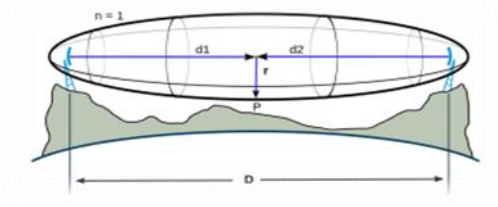

Fig.2. first Fresnel Zone of microwave link

The radius of the first Fresnel Zone at a given point can be calculated as:

r=17.3

Where r is the radius of the Zone in meters, d1and d2 are distances from the obstacle to the link end points in meters and D is the hop distance in km and f is the frequency in GHz.

III. METHODOLOGY

The process is iterative and goes through many redesign phases before the required quality and availability are achieved.

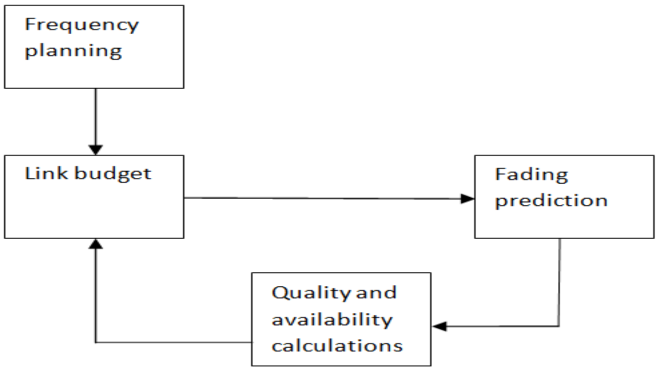

Fig.3. Microwave link design development

A. Frequency planning

Microwave links of short distances are generally allocated with higher frequencies and while for long hop distances or so we use lower frequencies.

B. Link Budget

The performance of any communication link depends on the quality of the equipment being used. Link budget is a way of quantifying the link performance.

C. Rain Fading

Rain attenuation is one of the series issues in microwave links. Rain attenuation increases with increase Hop length and the frequency. Jimma is a weather condition of precipitation 59%, humidity 63%, temperature 23degree centigrade, wind 3km/hr and light thunderstorm and rain.

D. Gas Absorption

A major difference in propagation through the real atmosphere versus free space is that there is air present. The two absorption peaks present in the frequency range of commercial radio links are located around 23 GHz, water molecules and 60 GHz, oxygen molecules.

E. Vapor Density

This variable reflects the humidity of the atmosphere in which the link is deployed. An average value of 7.5 is the default, though the table below reflects some other typical conditions from which to choose.

Table1. Vapor density at different temperature

Vapor Density	Surface Temperature	Surface Relative Humidity
0	7	0.000
3	11	0.300
7.5	15	0.584
10	19	0.612
13	23	0.631
15	27	0.581

F. Ground Reflection

The influence of reflection is that the ground can reflect some of the signals from the antenna to the receiving antenna .i.e. water surface and smooth ground have strong influence of reflection.

Changing the antenna heights can move the location of the reflection point. The formulas for getting the reflection point:

$$X \quad , \; Y$$

Where h1=first antenna height, h2=second antenna height, D=distance of the first site to the second site

$$\eta = \frac{1}{1+\sqrt{\frac{Y}{X}}}$$

Where d1=ηD, d2=D-d1, η = reflection point, D1 and d2 are distance of the site from the reflection point.

G. Fade Margins

Determining sufficient fade margin is the most important step in microwave link design. If the margin is too small, the link will be unstable – as a result, sufficient availability of the link or quality of the provided services cannot be guaranteed.

Fade margin using Barnett-Vienna Equation;

Equation considers the non-ideal and less predictable characteristics of radio wave propagation:

FM = 30 log D + 10 log (6ABf) – 10 log (1 –R) – 70

Where FM=Fade Margin, 30 log D = multi-path effect, 10 log (6ABf) = terrain sensitivity as shown table 1 below, 10 log (1 –R) = reliability objectiveness.

Table2. A and B values

A values	Land formation	B values	Climatic conditions
4	Smooth terrain, over water, or flat desert	0.5	Hot humid areas
1	Average terrain	0.25	Average inland areas, normal temperature areas
0.25	mountains, very rough, very dry terrain	0.125	Mountainous or very dry but non reflective areas

IV. ICROWAVE LINK DESIGN PROCESSES

To reach the stage where a radio link can be deployed and brought into service, several steps must be successfully completed.

A. Sites selections

Selection of a suitable microwave radio site encompasses a number of issues. The following factors should be considered:

- Geographical location for possible line of sight path obstruction,
- The possibility of future building construction along the path,
- The relationship of the site to any commercial, military or private airport within several kilometers.

➢ *Site A*

Site A is located inside Jimma University, main campus 110m from main ICT center. Its exact location is at 07 41’03.9”N latitude and 036 51’11.6”E longitude. Any vehicle via two-way lane of a distance can reach the site 10 meters from the main road. Actually, the proposed site was near to the ICT center and power lines.

Fig.5.Site A

➢ *Repeater site*

Repeater is located at Yebu town, 13.8 kilometers from site A. Its exact location is at 07 44’42.4”N latitude and 036 44’39.4”E longitudes, and at an elevation of 2098 meters above sea level. The site is 100 and 400meters distance from small and main roads respectively and 200 meters away from the commercial power line.

Actually, the selected site was mountainous and surrounded by corns and tree fields. There is no airport within site and a round, no high structures that may cause potential obstruction of signal.

Fig.6.Repeater site

➢ *SITE B*

It is located at Agaro town, campus under constructions. Its exact location is at 07 51’23.8”N Latitude and 036 36’50.6”E Longitude. A vehicle can reach the site, and 400meters from the main road. The site is 200 meters away from the commercial power line. Actually, future building construction could not reach the selected area.

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B. Path profile analysis

The path profile used to determine the height of the towers of the link, ensure free of obstructions, and not subject to the propagation losses from the radio phenomena. Elevation profile is generated from the geo-context profiler for the particular LOS path between sites. In this section site A to repeater and to site B path profiles were analyzed.

a) Site A to repeater site

Path profile was considered by 107meters and 92 centimeters from each following obstruction between these sites where considerations took place as shown table 1 below.

b) Repeater site to Site B

Path profile was considered by 148meters and 59 centimeters from each following obstruction between these sites where considerations took place.

- Earth Curvature (Eb) = where k = , tree height + ATG=15.24 meters
- First Fresnel Zone (F1) = 17.3 x √
- Total Extended Height = elevation + earth curvature +
- F1 + Tree Height plus ATG

Table3. Path profile from site A to repeater

obstacle	Differences of d1s' (km)	Dist. From Tx.d1(km)	Dist. from -Rx.d2 (km)	elevation(m)	Earth curvature (eb) (m)	first Fresnel clearance F1(m)	tree height +ATG(m)	total extended height (m)
1	0	0	13.8	1768.79236	0	0	15.24	1784.03236
2	0.10792	0.10792	13.6920799	1760.11243	0.086920625	1.730615356	15.24	1777.169963
3	0.10792	0.2158402	13.5841598	1753.3988	0.172471045	2.437795266	15.24	1771.24907
4	0.10792	0.3237603	13.4762397	1751.30896	0.256651259	2.973793662	15.24	1769.779405
5	0.10792	0.4316804	13.3683196	1747.69873	0.339461268	3.420064103	15.24	1766.698256
6	0.10792	0.5396005	13.2603995	1744.36584	0.420901071	3.808282412	15.24	1763.835028
7	0.10792	0.6475206	13.1524794	1742.13306	0.500970668	4.154753678	15.24	1762.028781
8	0.10792	0.7554407	13.0445593	1739.54321	0.579670088	4.469197809	15.24	1759.832081
9	0.10792	0.8633608	12.9366392	1738.71277	0.656999274	4.757968653	15.24	1759.367736
10	0.10792	0.9712809	12.8287191	1741.79041	0.732958225	5.02549382	15.24	1762.788857
11	0.10792	1.0792011	12.720799	1744.42957	0.807547034	5.275007058	15.24	1765.75212
12	0.10792	1.1871212	12.6128788	1744.99927	0.880765609	5.508956031	15.24	1766.628989
13	0.10792	1.2950413	12.5049587	1748.23499	0.952613972	5.729247782	15.24	1770.156847
14	0.10792	1.4029614	12.3970386	1746.67126	1.023092135	5.93740269	15.24	1768.871759
15	0.10792	1.5108815	12.2891185	1741.32886	1.092200086	6.134656287	15.24	1763.795714
16	0.10792	1.618802	12.1811984	1736.96472	1.159937838	6.322029087	15.24	1759.686689
17	0.10792	1.726722	12.0732783	1737.26025	1.226305378	6.500375551	15.24	1760.226935
18	0.10792	1.834642	11.9653582	1739.71533	1.291302718	6.67041976	15.24	1762.917055
19	0.10792	1.942562	11.8574381	1736.85083	1.354929846	6.832781555	15.24	1760.278541

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20	0.10792	2.050482	11.749518	1735.91699	1.417186775	6.987996474	15.24	1759.562175
21	0.10792	2.158402	11.6415979	1737.7948	1.478073491	7.136530823	15.24	1761.649404
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73	0.107921	7.770248	6.029752	1934.76233	2.756039319	9.74499984	15.24	1962.503368
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99	0.10792	10.57617	3.22383	2029.31055	2.005633772	8.313137212	15.24	2054.869318
100	0.10792	10.68409	3.11591	2037.18835	1.958274287	8.21440086	15.24	2062.60103*
101	0.10792	10.79201	3.00799	2032.44812	1.909544598	8.111553458	15.24	2057.709218
102	0.10792	10.89993	2.90007	2024.44568	1.859444706	8.004436541	15.24	2049.54956
103	0.10792	11.00785	2.79215	2031.89514	1.80797461	7.892876282	15.24	2056.835992
104	0.10792	11.115771	2.684229	2036.73901	1.755133816	7.776680359	15.24	2061.510828**
105	0.10792	11.223691	2.576309	2032.60071	1.700923302	7.6556399	15.24	2057.197271
106	0.10792	11.331611	2.468389	2017.91284	1.645342585	7.529520169	15.24	2042.327705
107	0.10792	11.439531	2.360469	2000.27209	1.588391665	7.398061401	15.24	2024.498548
108	0.10792	11.547451	2.252549	2001.63184	1.530070541	7.260973615	15.24	2025.66288
109	0.10792	11.655371	2.144629	2017.64514	1.470379215	7.117931582	15.24	2041.473452
110	0.107919	11.76329	2.03671	2023.57703	1.409318257	6.968570063	15.24	2047.194915
111	0.107922	11.871212	1.928788	2024.66541	1.346885368	6.812467591	15.24	2048.064758
112	0.10792	11.979132	1.820868	2027.20557	1.283083419	6.649156855	15.24	2050.377807
113	0.10792	12.087052	1.712948	2035.26917	1.217911268	6.478089681	15.24	2058.205166
114	0.10792	12.194972	1.605028	2040.9165	1.151368913	6.29863412	15.24	2063.606507
115	0.10792	12.302892	1.497108	2038.08252	1.083456355	6.110051101	15.24	2060.516027
116	0.10792	12.410812	1.389188	2042.39429	1.014173594	5.911467158	15.24	2064.559928
117	0.10792	12.518732	1.281268	2046.85059	0.94352063	5.701837448	15.24	2068.735944
118	0.10792	12.626652	1.173348	2033.60425	0.871497463	5.479894474	15.24	2055.19564
119	0.107918	12.73457	1.06543	2037.77856	0.798105466	5.244079588	15.24	2059.06075
120	0.10792	12.84249	0.95751	2054.71094	0.723341918	4.992418092	15.24	2075.666698
121	0.107923	12.950413	0.849587	2040.00903	0.647206031	4.722374332	15.24	2060.618614
122	0.10792	13.058333	0.741667	2030.22461	0.569702039	4.430604851	15.24	2050.464916
123	0.10792	13.166253	0.633747	2039.14404	0.490827844	4.112479323	15.24	2058.98735
124	0.10792	13.274173	0.525827	2062.198	0.410583445	3.761316239	15.24	2081.609898

125	0.10792	13.382093	0.417907	2082.58545	0.328968843	3.366793777	15.24	2101.521212
126	0.10792	13.490013	0.309987	2083.9624	0.245984039	2.911337777	15.24	2102.359724***
127	0.10792	13.597933	0.202067	2075.56079	0.161629031	2.359928344	15.24	2093.322348
128	0.10792	13.705853	0.094147	2084.0918	0.07590382	1.617226871	15.24	2101.024928
***	***	13.8	0	2098.000	0	0	15.24	2113.240

Table4. Path profile from repeater to Site B

obstacle	Differences of d1s' in (km)	Dist. From Tx.-d1(km)	Dist. from Rx.-2 (km)	elevation (m)	Earth curvature (eb)(m)	first Fresnel clearanceF1(m)	tree height + ATG (m)	total extended height (m)
	0	0	19	2097.93579	0	0	15.24	2113.17579
2	0.148594	0.148594	18.851406	2087.58398	0.16477681	1.142519542	15.24	2104.131281
3	0.148595	0.297189	18.702811	2067.35718	0.32695704	1.614184394	15.24	2084.538319
4	0.148594	0.445783	18.554217	2061.24121	0.4865385	1.975022593	15.24	2078.942772
5	0.148595	0.594378	18.405622	2045.07288	0.64352334	2.278315894	15.24	2063.234715
6	0.148594	0.742972	18.257028	2051.16797	0.79790945	2.544724269	15.24	2069.750602
7	0.148594	0.891566	18.108434	2069.78491	0.94969789	2.784852376	15.24	2088.759462
8	0.148594	1.04016	17.95984	2050.77197	1.09888866	3.005007486	15.24	2070.115869
9	0.148595	1.188755	17.811245	2038.9939	1.24548274	3.209303614	15.24	2058.688683
10	0.148595	1.33735	17.66265	2059.65332	1.38947912	3.400597821	15.24	2079.683397
11	0.148594	1.485944	17.514056	2065.13647	1.53087685	3.580976255	15.24	2085.488328
12	0.148594	1.634538	17.365462	2064.71216	1.66967691	3.752013473	15.24	2085.373849
13	0.148595	1.783133	17.216867	2082.33423	1.80588022	3.91493328	15.24	2103.295042*
14	0.148594	1.931727	17.068273	2073.80054	1.93948493	4.070711189	15.24	2095.050733**
15	0.148593	2.08032	16.91968	2049.9812	2.0704911	4.220101607	15.24	2071.511794
16	0.148596	2.228916	16.771084	2049.18262	2.1989022	4.363864561	15.24	2070.985384
17	0.148594	2.37751	16.62249	2045.19385	2.32471389	4.502439232	15.24	2067.261001
18	0.1486	2.52611	16.47389	2028.79773	2.44793284	4.636322189	15.24	2051.121985
19	0.14859	2.6747	16.3253	2014.97839	2.56854588	4.765910143	15.24	2037.55285
20	0.14859	2.82329	16.17671	2025.81189	2.68656139	4.891544007	15.24	2048.629995
21	0.148598	2.971888	16.028112	2028.77124	2.80198551	5.013520497	15.24	2051.826746
22	0.148594	3.120482	15.879518	2013.70105	2.91480883	5.13210087	15.24	2036.98796
23	0.1485948	3.2690768	15.730923	2037.17676	3.02503506	5.247515676	15.24	2060.689309***
24	0.1485942	3.417671	15.582329	2026.1853	3.13266317	5.359968593	15.24	2049.917935
25	0.148595	3.566266	15.433734	2004.76294	3.23769417	5.469642901	15.24	2028.710277
26	0.148594	3.71486	15.28514	1991.22314	3.34012678	5.576702703	15.24	2015.379974
27	0.148594	3.863454	15.136546	1994.92993	3.43996172	5.981549802	15.24	2019.591443
28	0.1485949	4.0120489	14.987951	1987.72302	3.53719957	6.354245937	15.24	2012.854468
29	0.1485941	4.160643	14.839357	1967.90613	3.63183923	6.700158563	15.24	1993.478126
30	0.148595	4.309238	14.690762	1976.28271	3.72388176	7.023245594	15.24	2002.269842
31	0.148594	4.457832	14.542168	1975.04395	3.81332599	7.326528169	15.24	2001.423799
32	0.148594	4.606426	14.393574	1961.73706	3.90017256	7.612373138	15.24	1988.489606
33	0.148595	4.755021	14.244979	1955.75842	3.98442202	7.882677693	15.24	1982.865523

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34	0.148594	4.903615	14.096385	1955.83228	4.06607323	8.138990945	15.24	1983.27734
35	0.1485947	5.0522097	13.94779	1945.97729	4.14512714	8.382595846	15.24	1973.745018
36	0.1485943	5.200804	13.799196	1919.55408	4.22158316	8.614570674	15.24	1947.630231
37	0.148594	5.349398	13.650602	1891.83948	4.29544136	8.835831623	15.24	1920.210751
38	0.148595	5.497993	13.502007	1876.3656	4.36670235	9.047164456	15.24	1905.019467
39	0.148594	5.646587	13.353413	1859.29834	4.43536519	9.24925042	15.24	1888.222955
40	0.148594	5.795181	13.204819	1855.06238	4.50143036	9.44268265	15.24	1884.246491
41	0.148595	5.943776	13.056224	1862.0802	4.56489829	9.48975131	15.24	1891.37485
42	0.148594	6.09237	12.90763	1856.81458	4.6257681	9.536319083	15.24	1886.216662
43	0.148595	6.240965	12.759035	1854.28247	4.68404064	9.582394016	15.24	1883.788905
44	0.148594	6.389559	12.610441	1851.31274	4.73971511	9.627983046	15.24	1880.920442
45	0.148595	6.538154	12.461846	1847.04834	4.79279225	9.805613579	15.24	1876.886746
46	0.148594	6.686748	12.313252	1861.91174	4.84327136	9.975980106	15.24	1891.970995
47	0.148594	6.835342	12.164658	1855.35864	4.89115281	10.13945317	15.24	1885.629249
48	0.148595	6.983937	12.016063	1834.98547	4.93643688	10.29635902	15.24	1865.45827
49	0.148594	7.132531	11.867469	1843.92871	4.97912297	10.44699448	15.24	1874.594828
50	0.148595	7.281126	11.718874	1835.69299	5.01921166	10.5916265	15.24	1866.543831
51	0.148594	7.42972	11.57028	1806.24377	5.0567024	10.73049763	15.24	1837.270974
52	0.148594	7.578314	11.421686	1784.43872	5.09159547	10.8638296	15.24	1815.634146
53	0.148595	7.726909	11.273091	1788.1698	5.12389108	10.9918234	15.24	1819.525514
54	0.148594	7.875503	11.124497	1804.17932	5.15358879	11.11466331	15.24	1835.687573
55	0.148595	8.024098	10.975902	1823.0708	5.18068902	11.23251894	15.24	1854.724009
56	0.148594	8.172692	10.827308	1824.3667	5.20519138	11.34554537	15.24	1856.157436
57	0.148594	8.321286	10.678714	1809.20813	5.22709608	11.45388525	15.24	1841.129111
58	0.148594	8.46988	10.53012	1811.12427	5.24640311	11.55767097	15.24	1843.168342
59	0.148595	8.618475	10.381525	1813.3468	5.26311257	11.65702357	15.24	1845.506938
60	0.1485947	8.7670697	10.23293	1802.81921	5.2772243	11.68118261	15.24	1835.017621
61	0.1485943	8.915664	10.084336	1776.78149	5.28873832	11.70507335	15.24	1809.015306
62	0.148594	9.064258	9.935742	1769.92908	5.29765464	11.7288769	15.24	1802.195609
63	0.148595	9.212853	9.787147	1774.48975	5.30397333	11.75205609	15.24	1806.785776
64	0.148594	9.361447	9.638553	1778.57739	5.3076943	11.84287225	15.24	1810.967959
65	0.148595	9.510042	9.489958	1771.87891	5.3088176	11.92956797	15.24	1804.357292
66	0.148594	9.658636	9.341364	1752.45679	5.30734321	11.95060892	15.24	1784.954739
67	0.1485945	9.8072305	9.1927695	1752.01697	5.30327114	11.97140249	15.24	1784.531641
68	0.1485945	9.955825	9.044175	1761.50928	5.29660139	11.99194005	15.24	1794.037819
69	0.148595	10.10442	8.89558	1757.27234	5.28733391	12.01223317	15.24	1789.811906
70	0.14859	10.25301	8.74699	1746.12781	5.27546917	12.09095027	15.24	1778.734227
71	0.1486	10.40161	8.59839	1718.07727	5.26100585	12.16579525	15.24	1750.744072
72	0.14859	10.5502	8.4498	1679.28394	5.24394588	12.23684017	15.24	1712.004722
73	0.148597	10.698797	8.301203	1664.46997	5.2242874	12.30415051	15.24	1697.238409
74	0.148593	10.84739	8.15261	1676.54199	5.20203178	12.36778655	15.24	1709.351811
75	0.1486	10.99599	8.00401	1690.69824	5.17717729	12.42780581	15.24	1723.543225
76	0.14859	11.14458	7.85542	1679.69043	5.14972686	12.44225183	15.24	1712.522408
77	0.148594	11.293174	7.706826	1684.18799	5.11967806	12.45647522	15.24	1717.004142
78	0.148595	11.441769	7.558231	1706.07312	5.08703136	12.47047795	15.24	1738.870629

79	0.148594	11.590363	7.409637	1715.64368	5.05178721	12.48426007	15.24	1748.419724
80	0.148595	11.738958	7.261042	1720.68567	5.01394512	12.49782187	15.24	1753.437436
81	0.148592	11.88755	7.11245	1705.50037	4.97350618	12.51116522	15.24	1738.225038
82	0.148597	12.036147	6.963853	1691.28357	4.93046814	12.5242901	15.24	1723.978328
83	0.148594	12.184741	6.815259	1695.99463	4.88483328	12.53719676	15.24	1728.656659
84	0.148594	12.333335	6.666665	1694.01123	4.83660075	12.54988702	15.24	1726.637718
85	0.148595	12.48193	6.51807	1684.66467	4.7857702	12.56236084	15.24	1717.252804
86	0.148594	12.630524	6.369476	1673.15332	4.73234232	12.5746184	15.24	1705.700281
87	0.148595	12.779119	6.220881	1652.13208	4.67631639	12.5866615	15.24	1684.635058
88	0.148594	12.927713	6.072287	1633.22559	4.61769315	12.63269438	15.24	1665.715973
89	0.148594	13.076307	5.923693	1650.71436	4.55647225	12.64367041	15.24	1683.154498
90	0.148595	13.224902	5.775098	1671.63562	4.49265324	12.65443548	15.24	1704.022709
91	0.148594	13.373496	5.626504	1678.96448	4.42623698	12.66498944	15.24	1711.295704
92	0.148594	13.52209	5.47791	1666.18811	4.35722306	12.6753324	15.24	1698.460666
93	0.148595	13.670685	5.329315	1668.95361	4.28561098	12.68546584	15.24	1701.16469
94	0.148594	13.819279	5.180721	1672.19507	4.2114017	12.69538954	15.24	1704.34186
95	0.148595	13.967874	5.032126	1655.48828	4.13459423	12.70510449	15.24	1687.56798
96	0.148594	14.116468	4.883532	1672.34705	4.0551896	12.71461066	15.24	1704.356846
97	0.148592	14.26506	4.73494	1682.02917	3.97318842	12.75055949	15.24	1713.992923
98	0.1486	14.41366	4.58634	1679.45325	3.88858502	12.78320744	15.24	1711.36504
99	0.148591	14.562251	4.437749	1668.38318	3.80138911	12.81257932	15.24	1700.237147
100	0.148595	14.710846	4.289154	1657.7229	3.71159317	12.83869783	15.24	1689.513191
101	0.148594	14.85944	4.14056	1666.72644	3.61920017	12.86158294	15.24	1698.447224
102	0.1486	15.00804	3.99196	1674.98022	3.52420561	12.86680097	15.24	1706.611231
103	0.14859	15.15663	3.84337	1672.22546	3.42661983	12.87181824	15.24	1703.763902
104	0.14859	15.30522	3.69478	1665.62793	3.32643651	12.87663512	15.24	1697.071001
105	0.148598	15.453818	3.546182	1648.36633	3.22365007	12.88125156	15.24	1679.711235
106	0.148594	15.602412	3.397588	1616.75122	3.11826869	12.88566792	15.24	1647.995157
107	0.148595	15.751007	3.248993	1596.96155	3.01028891	12.88988577	15.24	1628.101723
108	0.148593	15.8996	3.1004	1627.66748	2.89971293	12.8939013	15.24	1658.701095
109	0.148595	16.048195	2.951805	1635.02527	2.78653778	12.89771859	15.24	1665.949525
110	0.148595	16.19679	2.80321	1632.52283	2.67076492	12.90133666	15.24	1663.334929
111	0.148594	16.345384	2.654616	1643.60376	2.55239517	12.90475548	15.24	1674.30091
112	0.148595	16.493979	2.506021	1632.69397	2.43142693	12.9079753	15.24	1663.273372
113	0.148591	16.64257	2.35743	1631.15491	2.30786434	12.91099636	15.24	1661.613768
114	0.148597	16.791167	2.208833	1640.21936	2.18169905	12.91381862	15.24	1670.554878
115	0.148593	16.93976	2.06024	1650.5614	2.05293948	12.91644231	15.24	1680.770783
116	0.148596	17.088356	1.911644	1648.03943	1.9215796	12.91886761	15.24	1678.119876
117	0.148594	17.23695	1.76305	1634.83533	1.78762381	12.9210945	15.24	1664.784045
118	0.148595	17.385545	1.614455	1611.3219	1.65106941	12.92312315	15.24	1641.136092
119	0.148594	17.534139	1.465861	1612.70947	1.51191827	12.9249537	15.24	1642.386345
120	0.148595	17.682734	1.317266	1629.99084	1.37016849	12.92658614	15.24	1659.527599
121	0.148594	17.831328	1.168672	1639.22144	1.22582199	12.92802058	15.24	1668.615278
122	0.148592	17.97992	1.02008	1634.30896	1.07887981	12.93177971	15.24	1663.559619

123	0.1486	18.12852	0.87148	1632.71021	0.92933192	12.9323746	15.24	1661.811912
124	0.14859	18.27711	0.72289	1619.31543	0.77719647	12.92980571	15.24	1648.262432
125	0.1486	18.42571	0.57429	1619.01904	0.622453	12.92407112	15.24	1647.805567
126	0.14859	18.5743	0.4257	1636.08496	0.46512232	12.91516669	15.24	1664.70525
127	0.14859	18.72289	0.27711	1639.1322	0.30519412	12.91244459	15.24	1667.589841
128	0.1486	18.87149	0.12851	1634.48438	0.14265736	12.90952344	15.24	1662.776556
***	***	0	19	0	0	0	0	0

C. Tower heights calculations

Microwave tower is a structure built to enhance wireless communication, for them to work. They have to go long path using interconnecting pattern and can be located anywhere.

Tower heights calculation of the Site A to repeater site

As shown in Fig.8, the sites A, peak obstruction height, and repeater site are at Elevations of 1769, 2037 and 2098meters above sea level respectively.

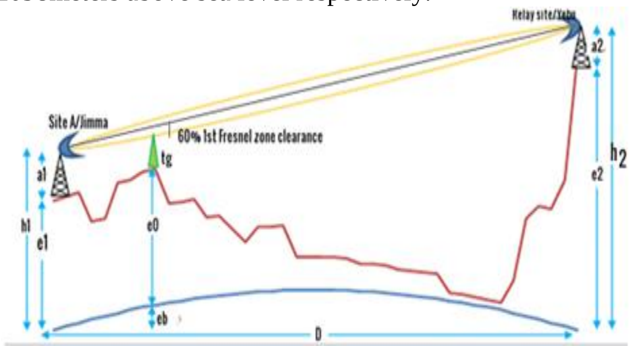

Fig.8. Tower heights calculation of Site A and Repeater

Values from the tables above; e_1 =1769m, D=13.8km, e_0=2037.2 m, d_1=10.68 km, e_2=2098m, d_2=3.116km, F=10.7GHz, k=4/3, TG=15.24m

E_b = = =1.958m

F_1 = 17.3 = 17.3 =8.214m

H=0.6 F_1= 0.6 =4.928 m

H_{01} = Eb + TG + e_0 =1.958m +15.24m+2037.2m= 2054.4 m

$h_1=a_1+e_1= a_1+1769m$, $h2=a_2+e_2= a_2+2098m$

Assuming $a_1= a_2= a$

H= [d1 (h: =

$$[10.684\left(\frac{a+2098m-a+1769m}{13.8}\right)]-2054.4m+a+1769$$

4.928m= $\left[10.684\left(\frac{329}{13.8}\right)\right]-2054.4m+a+17$a=35

.6 m=a_1=a_2

Where

E_b=Earth bulge, F_1=First Fresnel zone,

H=the first Fresnel zone at 60% clearance, TG=Tree growth

e_0=elevation of the obstruction, e_1=elevation of the site A

e_2=elevation of the repeater site, a_1=the first tower heights

a_2=the second tower heights, h_1= the height site A and elevation

h_2= the height of repeater site and elevation, H01=first peak obstruction height

Antenna orientation calculation

C $= absolute(longitude\ site\ A - longitude\ rep$

C=036 51'11.6" must be positive

C= 0 6'32.2" = 0.108944

$$\tan\frac{y-x}{2}=cot\frac{C}{2}\left(\frac{sin\frac{Latitude\ R-Latitude A}{2}}{cos\frac{Latitude\ R+Latitude\ A}{2}}\right)$$

$$\tan\frac{y-x}{2}=05°37'19.12"=5.6219779\ -79.914$$

$$\tan\frac{y+x}{2}=\cot\frac{C}{2}\left(\frac{\cos(\frac{Latitude\ R-Latitude\ A}{2})}{\sin(\frac{Latitude\ R+Latitude\ A}{2})}\right)$$

7835.4184776 →

X $=\frac{y+x}{2}-\frac{y-x}{2}=89.9926876-79.9$ 10.07859°

Y $=\frac{y+x}{2}+\frac{y-x}{2}=89.9926876+79$ 169.90678

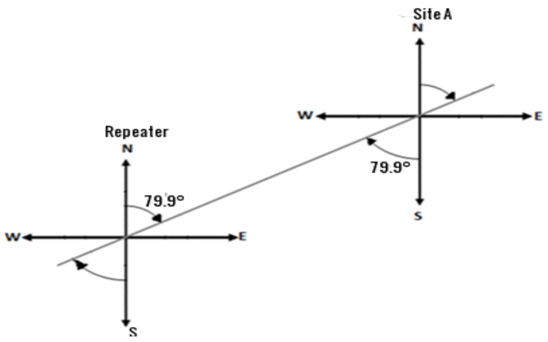

Fig.9.The first hop antenna orientations

Tower heights calculation of the repeater with site B

Repeater site, peak obstruction height, and Site B are at elevations 2098, 2082, and 1628meters above sea level respectively.

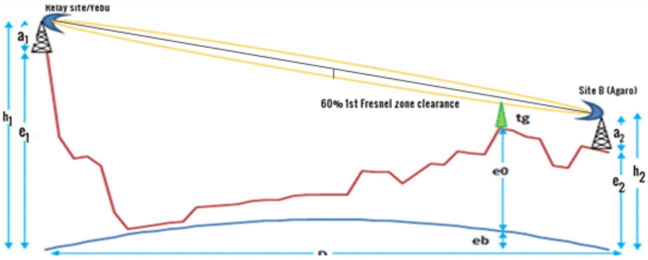

Fig.10.Tower heights calculation of Repeater and Site B

Values from the tables above; e1=2098m, D=19km, e_0=2082.33 m, d1=1.78km, e_2=1628m, d_2=17.22km, F=8.5GHz

E_b = = =1.803m

F_1 = 17.3 =17.3 =7.54 m

H=0.6 F_1= 0.6 =4.522 m

H_{01}= Eb + TG + e_0 =1.803m +15.24m+2082.33m= 2099.37

$h_1=a_1+e_1= a_1+2098m$, $h_2=a_2+e_2= a_2+1628m$

Assuming $a_1= a_2= a$

H= $[d1\left(\frac{h2-}{l}\right.=$

$[1.78\left(\frac{a+1628m-a+2098m}{19}\right)] - 2099.37m + a + 209$

4.522m= $\left[1.78\left(\frac{-470}{19}\right)\right] - 2099.37m + a + 20$a=49.

92 m=a_1=a_2

The second hop antenna orientation calculation

C $= absolute(longitudeR -$

C= $036°44'39.=$ 0.130222

0.864227358

6483.216898

X $= \frac{y+x}{2} - \frac{y-x}{2} = 89.991162° - 40.83447° = 49°9'24$;

Y $= \frac{y+x}{2} + \frac{y-x}{2} = 89.99116° + 40.83447° = 130°49'32.$

Site R: N ($90° - 49°9'24.09'' = 40$or N

(

Site B: S ($130°49'32.16'' - 90° = 4$ W or S

(W

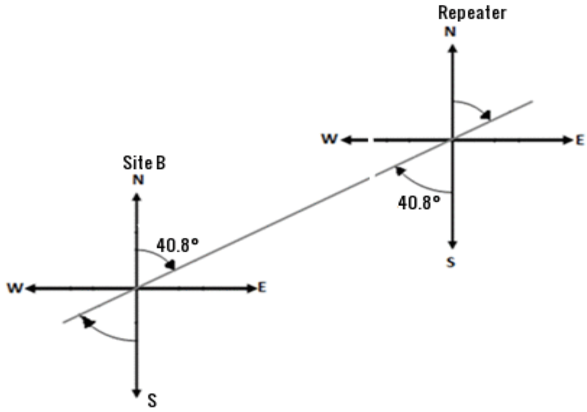

Fig.11.The second hop antenna orientations

V. ANALYSIS AND RESULTS

The analysis of the two hop lengths consist of the following steps: free space loss, link budget, rain attenuation, fade margin, and Fresnel zone calculations.

A. Site A to Repeater site

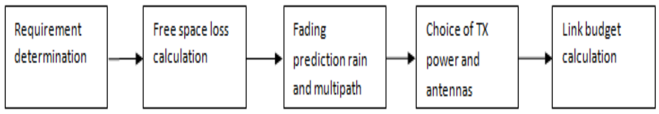

Fig.12. Design flowchart

Step 1-Requirement Determination

Transmission requirements:

Maximum data rates > 155 Mbps

Minimum required availability: 99.999%

Ray parameters:

10.7GHz

Modulation 16 QAM; BW=28MHz; Ps (10^{-6}) =-80.8 dBm

Tx/Rx spacing 490MHz, TX power=26 dBm

Step 2-Free space loss calculation

FSL = 92.4 + 20 log f $_{(GHz)}$ + 20 log D $_{(km)}$ =92.4 + 20 log 10.7 + 20 log 13.8=135.8 dB

Step 3-Rain attenuation

For 99.999% availability in rain zone J the rain rate is $R_{0.001}$=55 mm/hr

For f=10.7 GHz k_h=0.017; α_h=1.227; k_v=0.017; α_v=1.178

Vertical polarization

$\gamma R_{0.001}$ = kv .$R^{\alpha v}_{0.001}$ = 0.017 * $(55)^{1.178}$ = 1.924dB/km

Horizontal polarization

γR0.001 = k_h .$R^{\alpha h}_{0.001}$ = 0.017 ·*$(55)^{1.227}$ = 2.32 dB/km

Step 4 –link budget

The link budget is a calculation involving the gain and loss factors associated with the antennas, transmitters, transmission lines and propagation environment.

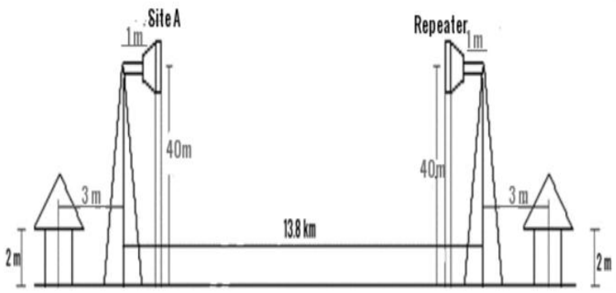

Fig.13. Link budget of Site A to Repeater

Site A Link Budget

Transmitter Gain: The diameter of 1.8m, and the gain,
$G = 17.8 + 20 \log (f_{GHz}) + 20 \log (d_m) = 17.8 + 20 \log 10.7 + 20 \log (1.8) = 43.5$ dB

Wave Guide Loss
Elliptical waveguide type (WR90),
$L_{WG\ (TX)}$ =40 m+3m-2 m +1 m+5 m =47 m ( ) = 4.58 dB

Branching loss
Branching loss (Lb_{Tx}=2 dB)
Radome loss
Radome loss (Lr_{Tx}=0.5dB)

Repeater site Link budget

$G_R = 17.8 + 20 \log (f_{GHz}) + 20 \log (d_m)$
$= 17.8 + 20 \log (10.7) + 20 \log (1.8) = 43.5$dB
Wave Guide Loss
$L_{WG(R)}$ =40m+3m-2m +1 m+5m =47 m ( ) =4.58 dB

Branching loss
Branching loss (Lb_R =2 dB)
Radome loss
Radome loss (Lr_R=0.5dB
Miscellaneous losses
Miscellaneous Loss (L_{misc}=2dB)

B. Repeater site to site B
Link parameters:
Data rates: >155Mbps
Minimum required availability: 99.999%
Ray parameters:
8.5GHz
Modulation 16QAM; BW=28MHz; Ps (BER 10^{-6})
= -80.6dBm
Tx/Rx spacing = 490MHz
TX power=28 dBm

Step 2-Free space loss calculation
$FSL = 92.4 + 20 \log f_{(GHz)} + 20 \log D_{(km)} = 92.4 + 20 \log 8.5 + 20 \log 19 = 136.6$ dB

Step 3-Rain attenuation

For f=8.5 GHz k_h=0.0057; α_h=1.316; k=0.0050; α_v=1.303

Vertical polarization
$\gamma R0.001 = kv\ .R^{\alpha v}{}_{0.001} = 0.005 * (55)^{1.303} = 0.926$ dB/km

Horizontal polarization
$\gamma R0.001 = k_h\ .R^{\alpha h}{}_{0.001} = 0.0057 * (55)^{1.316} = 1.112$ dB/km

Step 4 –link budget

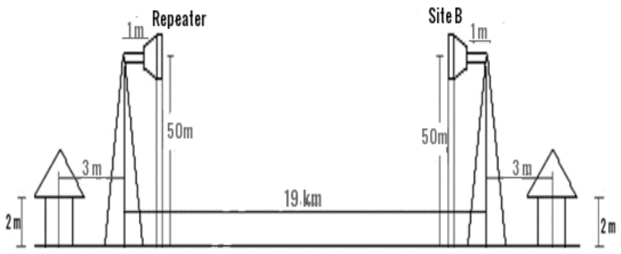

Fig.14. Link budget of Repeater site to Site B

Repeater site link budget
Antenna gain
The diameter of reflector antenna 1.8m, and the gain,
$G = 17.8 + 20 \log (f_{GHz}) + 20 \log (d_m) = 41.5$ dB
Wave Guide Loss
$L_{WG(R)}$ = $50m - 2m + 3m + 1m +$! and 5.84dB/100m loss,
$L_{WG(R)}$ = 187ft ( ) =57m ( ) = 3.33dB

Branching loss
Branching loss (Lb_R=2 dB)
Radome loss
Radome loss (Lr_R=0.5dB)

Site B Link budget

Gain
$G_{Rx} = 17.8 + 20 \log (f_{GHz}) + 20 \log (d_m) = 17.8 + 20 \log (8.5) + 20 \log (1.8) = 41.5$dB
Wave Guide Loss
$L_{WG\ (Rx)}$ $= 50m - 2m + 3m$=57 m 57 m
( ) = 3.33dB

Branching loss
Branching loss (Lb_{Rx} =2 dB)
Radome loss
Radome loss (Lr_{Rx} =0.5dB)
Miscellaneous losses
Miscellaneous Losses (L_{misc}=2dB), e.g antenna misalignment, TX variation loss,

C. Reflection Point Calculation
The formulas for getting the reflection point

$X \quad , \; Y \quad \eta$

Where d1= ηD, η =reflection point, D and d1 are distance of the site from the reflection point.

X , Y

η = = =0.5, D1=0.5*13.8=6.9 km

d_2=D-d_1=13.8 km -6.9 km=6.9 km

x , y

η = = =0.5, d1= ηD, d_2=D-d_1,

D1=0.5*19=9.5 km, d_2=19-9.5=9.5km

VI. RESULTS

Clearance verification of site A, repeater and site B

From the determined path profile, hop length, the frequency planned, and tower height calculations we have got the following Fresnel zone clearance.

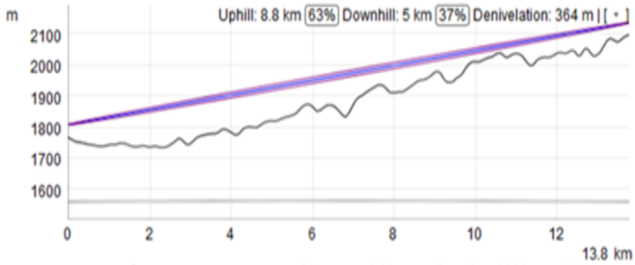

Fig.15. Clearance verification of site A to repeater

The second result was from longer hop length than that of the first hop length relatively.

Fig.16. Clearance verification of repeater to site B

A. Transmitter

The voice or data channels are combined by a multiplexing. This signal is frequency modulated to an IF in the indoor unit and by elliptical wave guide to the outdoor unit and then up converted to the RF for transmission through the atmosphere.

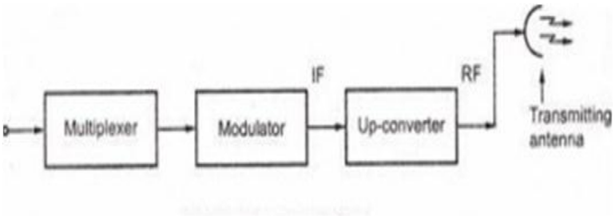

Fig.17. Transmitter's blocks diagram

Table 5.Transmitter products and specifications

Model	Product type	Specifications
SN74CBTLV 3257		**1 Features** • 5-Ω Switch Connection Between Two Ports • Rail-to-Rail Switching on Data I/O Ports • I_{off} Supports Partial-Power-Down Mode Operation • Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II • ESD Protection Exceeds JESD 22 – 2000-V Human-Body Model (A114-A) – 200-V Machine Model (A115-A) **2 Applications** • Internet of Things • Wireless Headphones • Television Set • 4-Bit Bus Multiplexing and Demultiplexing
SSM0812		**Features** • RF output/carrier input .... 8 to 12 GHz • Modulation bandwidth .... DC to 500 MHz (Q) • Linear RF input .... Up to +5 dBm • IF input power .... +10 to +13 dBm • Sideband suppression .... 25 dB • Carrier rejection .... 35 dB • IF options: Single sideband .... A, B and C (internal hybrid) Multioctave IFs .... Q (separate inputs)
TX221415		*X-band Up/Down Block Converter* Specifications Frequency: RF/LO – C Band, X Band, KU Band; IF In – L Band Bandwidth: 2 - 8% Passband Ripple: ±0.2 dB / 10 MHz Gain: [illegible] RF Image Reject: 60 dBc LO Leakage: 60 dBc (@ output power [illegible]) All Spurious Response: < -40 dBm Output Power Monitor: [illegible] LO Power Requirement*: +12 - [illegible] dBm Output P_1 dB: [illegible] IP_3: [illegible]
222040-2		**Characteristics** **Type Numbers** Super Premium Waveguide, Standard Jacket — EWP90S Premium Waveguide, Standard Jacket — EWP90 Standard Waveguide, Standard Jacket — EW90 Premium Waveguide, Fire Retardant, Non-Halogenated Jacket — 35409-16* Premium Waveguide Type CATVP — 222040-2 **Electrical** Max. Frequency Range, GHz — 8.3-11.7 $_eTE_{11}$ Mode Cutoff Frequency, GHz — 6.50 Group Delay at 11.2 GHz, ns/100 ft (ns/100 m) — 125 (410) Peak Power Rating at 11.2 GHz, kW with 190 series connectors — 44.9 with 290 series connectors — 30.8
		ODU features and specificatons
UHX6-102		**General Specifications** Antenna Type — UHX - Ultra High Performance Parabolic Shielded Antenna, Diameter, nominal — 1.8 m | 6 ft Packing — Standard pack Radome Color — White Radome Material — Enhanced Reflector Construction — One-piece reflector Antenna Input — UBR100 Antenna Color — Gray

B. RF repeater

In order to overcome the problems of line-of-sight and power amplification of weak signals, microwave systems use repeaters depending on non-line of sight and interferences. The repeater is placed in line-of-sight of the transmitting and receiving stations. The data signals are received, mixed with local oscillator, and re-transmitted to the receiver.

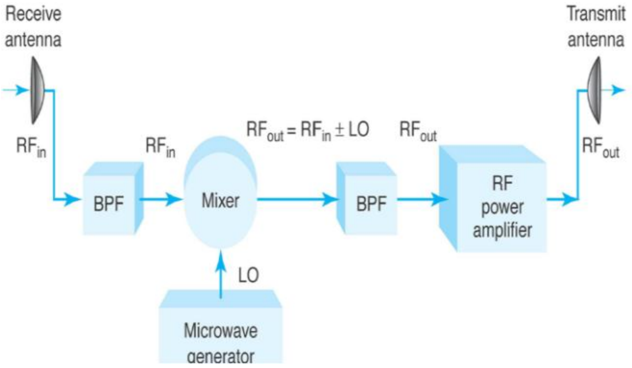

Fig.16. RF repeater block diagram

Based on the repeater block diagram above the parameters product and specifications are given.

Table 6.RF repeater products and specifications

Model	Product types	Specifications
19558		**Specifications:** Passband: 10.7 - 11.7 GHz Passband Loss: 0.2 dB Typ Passband VSWR: 1.25:1 Max Rejection: 80 dB Typ / 70 dB Min from 12.75 - 14.50 GHz Flanges: WR75 Cover Dimensions: 3.25" x 1.5" x 1.5" (82 mm x 38 mm x 38 mm) Finish: White Lacquer
SM1807		SM1807 Microwave Mixer LO=+7 dBm 2-20 Ghz **Electrical Specifications:** RF Frequency: 2.0 – 20.0 Ghz LO Frequency: 2.0 – 20.0 Ghz IF Frequency: DC – 2.0 Ghz LO Drive: +7 dBm Typ Conversion Loss: 7.0 4-20 Ghz dB Max 12.0 2-20 Ghz dB Max Isolation L-R: 25 dB Min Isolation L-I:: 20 dB Min Input 1 dB compression: 0 dBm Typ
PB1049CB		Designed for converter applications for suppressing LO leakage and transmitter signals Passband 8.55 to 9.35 GHz Passband Insertion loss 0.7 dB typical Passband Return loss 20 dB min Rejection: DC to 5.15 GHz 90 dB min 7.9 to 8.4 GHz 20 dB min 10 to 20 GHz 80 DB min Converter SMA Female (alternatives available)
PE15A407		X-band high gain power amplifiers/specifications Frequency, Min 8.5 GHz Frequency, Max 11 GHz Gain, Min 30 dB Gain Flatness 1.25 dB 1dB Compression Point, Min 3 Watts 3rd Intercept Point, Typ 45 dB 3rd Intercept Point, Min 44 dB Voltage, DC Typ 12 Volts Current, DC Typ 5,000 mA

C. Receiver

The reverse process of the transmitter occurs at the receiver. In this part the products: down converter, demodulator and demultplexer are introduced in table 5.3 above.

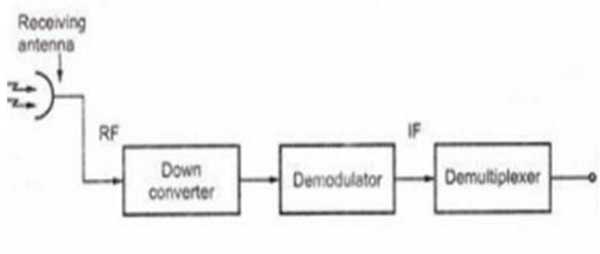

Fig.17.Receiver's block diagram

Table7.Receiver products and specifications

Model	Product types	Specifications
HSX6-82		**High Performance Antennas** - Super High Cross Polarization Discrimination – Dual Polarized Diameter, nominal 1.8 m | 6 ft Polarization Dual **Electrical Specifications** Beamwidth, Horizontal 1.4 ° Beamwidth, Vertical 1.4 ° Cross Polarization Discrimination (XPD) 40 dB Electrical Compliance ETSI Class 3 Front-to-Back Ratio 67 dB Gain, Low Band 41.3 dBi Gain, Mid Band 41.4 dBi Gain, Top Band 41.7 dBi Operating Frequency Band 8.200 – 8.500 GHz Radiation Pattern Envelope Reference (RPE) 1222E | 1224B Return Loss 30.7 dB VSWR 1.06
35409-24		EWP77-71W,HELIAX® premium Elliptical Waveguide,7.125-8.5GHz,black non halogenated,fire retardant polyolefin jacket

D. Horn antenna simulation and design

The basis for this given design was to implement standard gain horn, directivity, electric and magnetic waves in near and far field propagations using Feko suite 5.5. The horn antenna we designed for the link was subjected to the following constraints:

- perating frequency at 8.5GHz and10.7GHz, Maintain gain of 20 dB over the frequency
- imensions of rectangular waveguide (in mm): width x height x length 42 x 35 x 75 respectively

a) At 10.7GHz flared out waveguide design

As shown Fig.18 below the mesh of flared out wave guide and electric field density with respect to the colors starting from the center, on top left numerical values. The right figure is the gain of far field at 10.7GHz frequency. Vertically at zero degree the gain is greater than elsewhere.

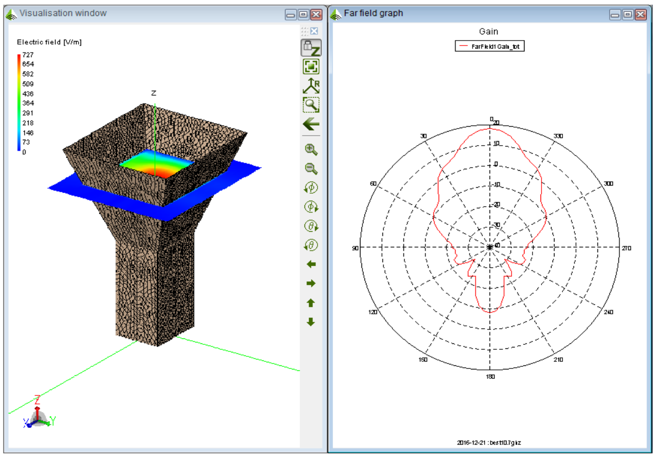

Fig.18. waveguide model and gain in polar plane

b) At 8.5GHz flare out waveguide design

From the graph of Fig.19 below as angles increases right and the electric field decreases. 3.84 mesh size of flared out wave guide and electric field density with respect to the colors starting from the center to the edges, on top left numerical values. The right figure is the gain at 8.5GHz frequency. The waveguide is vertically polarized, at zero degree the gain is greater actually less than at 10.7GHz frequency.

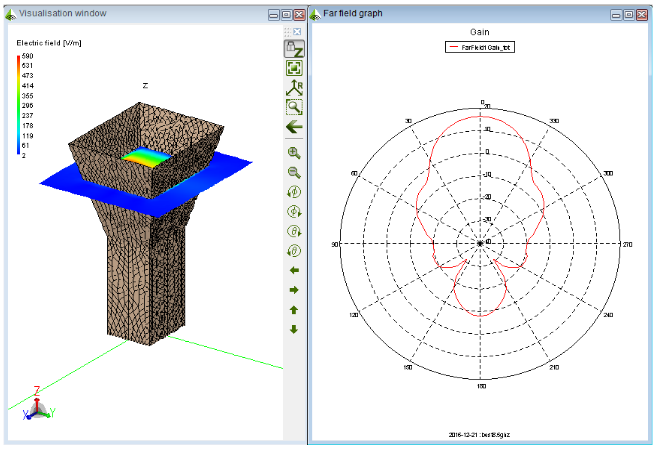

Fig.19. Waveguide model and gain in polar plane at 8.5GHz

VII. CONCLUSION

In this thesis, the designed point to point microwave link communication between Jimma Main Campus and Agaro branch by means of geo-context profiler for path profile data's, feko suite 5.5 for flared out waveguide feeder design. Microwave link works on LOS and is not the same as optical line of sight; as a result it requires more clearance than optical line of sight to accommodate the characteristics of microwave signals; such as line of sight, Fresnel zone clearance, and free space loss considerations. The path profile for the two hop lengths were analyzed; The path profile for Site A to repeater is intended to use 107meters and 92 centimeters from each obstructions within the path, and 148meters and 59 centimeters for Repeater Site to Site B . The tower height calculations, angle of elevations and azimuth, Link budget calculations, signal to noise ratio calculations, reflection point calculations were also conducted.

The designed rectangular horn antennas have directional radiation pattern, ability to achieve high gain and directivity.

Reflection points that account for response signal fading are devised for different antenna heights, choosing high elevation of repeater site that is line of sight with both transmitter and receiver.

A. Future works

The designed microwave link in this thesis is depended on the transmission of only data and audio, video is not included. Therefore, further research could focus on video transmission and reception as with data and audio in wireless communication system of the link. Within the path of multipath/rain fading, Doppler shift, phase error, etc. was not considered that can be added to the channel, in order to closely simulate real life systems.

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Gemechu Dengia received the B.Sc. degree in electrical and computer Engineering/communications from Jimma University, Jimma, Ethiopia, in 2012. And he received the M.Sc. degree in communications engineering (with Very Great Distinction) from Jimma University, Jimma, Ethiopia, in 2016.

Since 2012, he has been with the Department of Electrical and Computer Engineering, Jimma University, Jimma, Ethiopia.
Currently, he is working as a lecturer in Mizan-tepi University.
His research interests include Microwave communications and signal processing. Satellite .Radar communications.

Tofik Jemal received the B.Sc. degree in electrical engineering from Bahir dar University, Bahir dar, Ethiopia, in 2001 and the M.Sc. degree in computer engineering from Delhi University, New Delhi, India, in 2005, and the Ph.D. degree in wireless communication engineering from Rostock University, Rostock, Germany, in 2014.

Since 2001, he has been with the department of Electrical and Computer Engineering, Jimma University, Jimma, Ethiopia. He is also currently working as a directorate of Research and publication office of Jimma Institute of Technology, Jimma University. His research interests include wireless communication, information theory, resource optimization for wireless networks, routing protocols, sensor networks, and AD HOC networks.

Sherwin N. Catolos received the B.Sc. degree in electronics and communication Engineering from Cagayan State University, Tuguegarao City, Cagayan Philippines 3500 in April 2001. And he received the M.Sc. degree in communications Engineering from University of St. Louis Tuguegarao City, Cagayan Philippines in May 2008.

From June 2002 to March 2009 , he has been with the Department of Electronics and Communication engineering as instructor at University of Saint Louis, Tuguegarao City and From May 2009 – February 2010 as Electronics Engineer, Sustaining Engineer at ESCO Micro Pte Ltd, Singapore 486 777. Currently, he is working as Assistant Professor in Jimma University.