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Optimization of a Point-to-Point Microwave Link and Reducing the Effect of Atmospheric Ducting on Microwave Transmission Network

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Abstract: The mobile operators often use point-to-point microwave connections for feeder links in their access network. Now as the microwave signal propagates, it might get trapped between different atmospheric layers called duct that no doubt affects received signal level (RSL) at the receiving station. This paper presents a short description of Microwave link optimization procedure and proposed optimization for some of the malfunctioning microwave links of famous telecommunication services provider 'Telenor Pakistan'. We propose a method for avoiding the signal transmission through the ducting region through the use of duct detection and avoidance system in order to improve the quality of the cellular transmission network.

Keywords: microwave link, atmospheric layers, optimization, Telenor Pakistan, duct, quality.

1. INTRODUCTION

In the process of network optimization, there are many uncertain factors, such as the increase of client's amount, the change of the surface features and the necessity of the new services provided, which makes mobile communication networks a ceaseless expanding and updating system (Du *et al*., 2005). To keep the networks in a good working state, network optimization has to be performed continually and frequently (Du *et al*., 2005). Microwave link optimization (Sayed *et al*., 2005) is a systematic process and any link that is malfunctioning or undergoes any kind of problem passes through a series of phases towards successful operation. These phases are described below and the cellular transmission optimization (Mishra, 2004, Mishra, 2006) in **(Fig. 1)**:

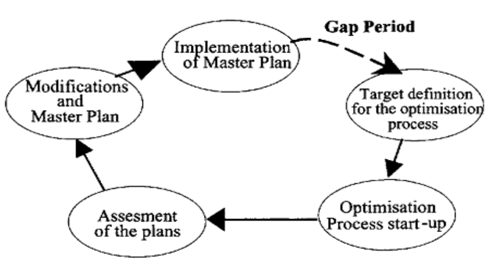

Fig. 1: Cellular transmission network optimization cycle (Mishra, 2004)

1. First of all target areas for link optimization are determined i.e. either there is a need to increase capacity or the existing capacity is enough but the quality of services (QoS) provided is not acceptable.

2. For cases when optimization is solely for the purpose of improving performance of microwave link, the next step after the target areas definition is to check key performance indicators (KPI's) i.e. errored seconds (ES), severely errored seconds (SES) and errored second ratio (ESR) for tracing the cause of link performance degradation. For the scenarios when the soul of optimization process is improvement in capacity, initial plans are made and assessed based on cost, quality and time.

3. After analyzing the field data and KPI's, some additional parameters are also checked against planned link data because it might happen that during the link planning and commissioning phase future vegetation growth or many other scientific aspects were not given a proper attention by the transmission planning engineers. So a thorough study of link profile must be carried out in order to make sure that no mistakes were committed at the time of link planning.

4. Finally after examining different link performance parameter and various scientific aspects (e.g. rain rate, earth radius and k factor, different climatic and atmospheric phenomenons, line of sight (LOS) considerations), a proper remedy is applied for a better link performance. For the case of capacity up gradation after assessing initial plans a master plan is made which again after assessment based on revenue and quality is implemented.

The next section present some optimization case studies that were carried out at Telenor Pakistan

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(Telenor, 2011) followed by a proposed method of finding the region where atmospheric duct occurs and avoiding transmission of signals through that region.

2. MATERIALS AND METHODS

CASE STUDIES

First Case: The first case that we encountered was because of 'Wrong Frequency Designation'. The network management system (NMS) encountered an alarm for communication failure between two sites IMM001 and PTCL_Ghalanai (PTCL's Microwave link). The level one support team visited the site to check whether the problem is due to faulty equipment or the power outage. The field team reported that problem is occurring due to some other reason and that equipment and power is fine. So now the next step was to check different link parameters. While examining multiple parameters the only cause of communication failure was observed to be wrong frequency designation at the transmitting and receiving stations as shown in **(Fig. 2)**. For successful communication the centre frequency at both the stations must be same which in this case is different at end station A and B. So the proposed optimization was to assign same centre frequency band to both the stations A and B either 22.496300 or 21.264300 GHz.

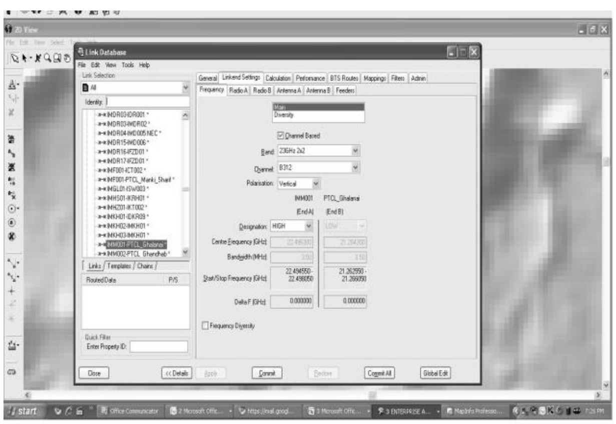


Fig. 2: Wrong frequency designation at transmitting and receiving station

Second Case: The next issue that we encountered was fluctuation in received signal level (RSL) between the sites IUSW05 and IUSW13. Some time the RSL was perfect but sometimes it was so weak that the equipment was unable to read it. At the beginning after examining the LOS report task seemed a bit difficult, but as the link parameters examination went on finding the cause of problem became much easier than it seemed to be difficult in the beginning. The problems observed were the 'Multipath' effect at the receiving station as indicated in (**Fig. 3)**. Different multipath signals that produced constructive interference at one time produced destructive interference the other time which was the cause of fluctuation in RSL. These fluctuations were producing results that were not acceptable at all, so the proposed optimization was the change in antenna heights at the transmitting and receiving stations **(Fig. 4)**.

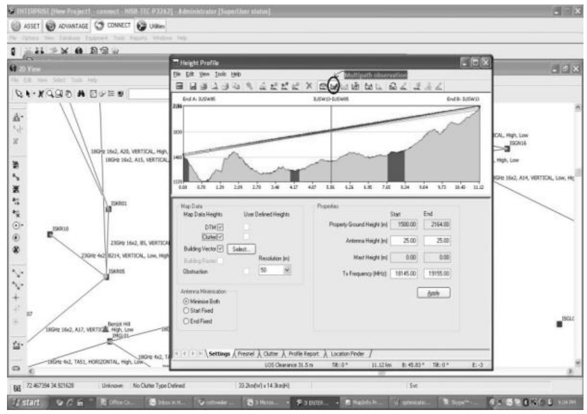


Fig. 3: Multipath observation

Fig. 4: Rearranged antennas

As the antenna heights were varied and reflection analysis was done the effects of multipath were reduced significantly as shown in **(Fig. 5)**.

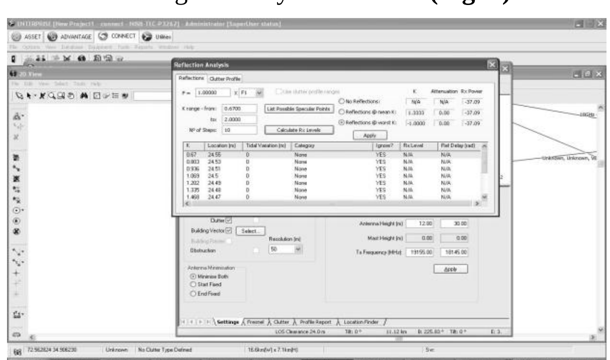
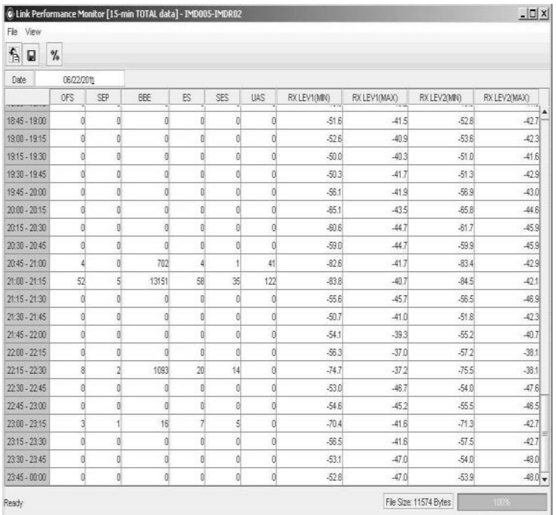


Fig. 5: Reflection analysis

Third case: A large no of customer complaints regarding dropped calls and poor quality of services provided made the optimization team to examine closely the link between the sites IMD005 – IMDR02.

Fluctuations in RSL were observed again on the mentioned sites as shown in **(Fig. 6),** but this time the cause of problem was not multipath effect. Fluctuations were faced before on the same link, but were reported by the Network Operations Center (NOC) this time. No power outage was observed by the level 1 team (field team). Additionally, it was also reported that the link configuration is according to the planned data.



Link Performance Monitor [15-min TOTAL data] - IMD005-IMDR02

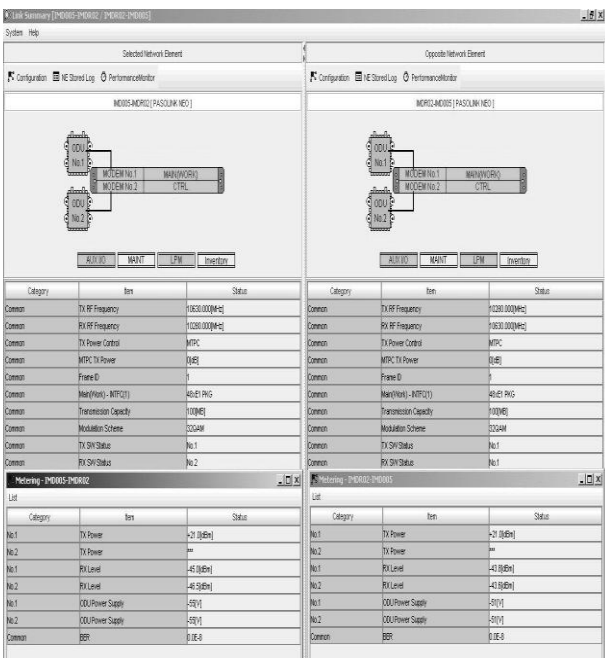
Date 06/22/2011

	OFS	SEP	BBE	ES	SES	UAS	RX LEV1(MIN)	RX LEV1(MAX)	RX LEV2(MIN)	RX LEV2(MAX)
18:45 - 19:00	0	0	0	0	0	0	-51.6	-41.5	-52.8	-42.7
19:00 - 19:15	0	0	0	0	0	0	-52.6	-40.9	-53.6	-42.3
19:15 - 19:30	0	0	0	0	0	0	-50.0	-40.3	-51.0	-41.6
19:30 - 19:45	0	0	0	0	0	0	-50.3	-41.7	-51.3	-42.9
19:45 - 20:00	0	0	0	0	0	0	-56.1	-41.9	-56.9	-43.0
20:00 - 20:15	0	0	0	0	0	0	-65.1	-43.5	-65.8	-44.6
20:15 - 20:30	0	0	0	0	0	0	-60.6	-44.7	-61.7	-45.9
20:30 - 20:45	0	0	0	0	0	0	-59.0	-44.7	-59.9	-45.9
20:45 - 21:00	4	0	702	4	1	41	-82.6	-41.7	-83.4	-42.9
21:00 - 21:15	52	5	13151	58	35	122	-83.8	-40.7	-84.5	-42.1
21:15 - 21:30	0	0	0	0	0	0	-55.6	-45.7	-56.5	-46.9
21:30 - 21:45	0	0	0	0	0	0	-50.7	-41.0	-51.8	-42.3
21:45 - 22:00	0	0	0	0	0	0	-54.1	-39.3	-55.2	-40.7
22:00 - 22:15	0	0	0	0	0	0	-56.3	-37.0	-57.2	-38.1
22:15 - 22:30	8	2	1093	20	14	0	-74.7	-37.2	-75.5	-38.1
22:30 - 22:45	0	0	0	0	0	0	-53.0	-46.7	-54.0	-47.6
22:45 - 23:00	0	0	0	0	0	0	-54.6	-45.2	-55.5	-46.5
23:00 - 23:15	3	1	16	7	5	0	-70.4	-41.6	-71.3	-42.7
23:15 - 23:30	0	0	0	0	0	0	-56.5	-41.6	-57.5	-42.7
23:30 - 23:45	0	0	0	0	0	0	-53.1	-47.0	-54.0	-48.0
23:45 - 00:00	0	0	0	0	0	0	-52.8	-47.0	-53.9	-48.0

Ready File Size: 11574 Bytes

Fig. 6: Link performance history

On examining the link parameters in detail as shown in **(Fig. 7),** the observed area for optimization



Category	Item	Status
Common	TX RF Frequency	10630.000[MHz]
Common	RX RF Frequency	10280.000[MHz]
Common	TX Power Control	MTPC
Common	MTPC TX Power	0[dB]
Common	Frame ID	1
Common	Main(Work) - INTFC(1)	48xE1 PKG
Common	Transmission Capacity	100[MB]
Common	Modulation Scheme	32QAM
Common	TX SW Status	No.1
Common	RX SW Status	No.2

Category	Item	Status
No.1	TX Power	+21.0[dBm]
No.2	TX Power	***
No.1	RX Level	-45.0[dBm]
No.2	RX Level	-46.5[dBm]
No.1	ODU Power Supply	-55[V]
No.2	ODU Power Supply	-55[V]
Common	BER	0.0E-8

Category	Item	Status
Common	TX RF Frequency	10280.000[MHz]
Common	RX RF Frequency	10630.000[MHz]
Common	TX Power Control	MTPC
Common	MTPC TX Power	0[dB]
Common	Frame ID	1
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Common	Modulation Scheme	32QAM
Common	TX SW Status	No.1
Common	RX SW Status	No.1

Category	Item	Status
No.1	TX Power	+21.0[dBm]
No.2	TX Power	***
No.1	RX Level	-43.8[dBm]
No.2	RX Level	-43.6[dBm]
No.1	ODU Power Supply	-51[V]
No.2	ODU Power Supply	-51[V]
Common	BER	0.0E-8

Fig. 7: Link summary IMD005 – IMDR02

was bit error rate (BER). Standard BER is defined as 10exp-6, but the implemented BER was 10exp-8. This caused even the signal with very minute error to be discarded, which was the main reason of large number of dropped calls and poor quality of service. So the proposed optimization was to change the BER from 10exp-8 to 10exp-6.

Fourth case: (Fig. 8) shows a case where a building under construction was obstructing the LOS between the sites IB1004 – IB1007. This was the only reason for performance degradation, so the proposed optimization was rerouting of traffic from site IB1004 to site IB1007 through site IB1005.

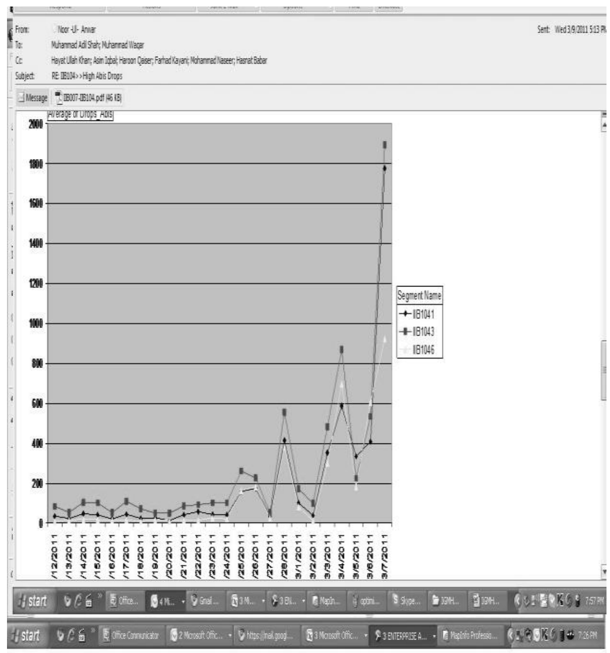

Fig. 8: LOS blockage due to building construction

3. DISCUSSION

PROPOSED METHOD

Atmospheric ducting is a mode of propagation of electromagnetic radiation, usually in the lower layers of earth's atmosphere, where the waves are bent by atmospheric refraction (Wikipedia, 2011). Coastal areas worldwide are known to be especially 'rich' in super refractive layers and ducts that affect microwave propagation (Turton *et al.,* 1988). Atmospheric ducts arise when warm air from a dry landmass moves over the cooler sea water (Sirkova and Mikhalev, 2003). In stable formations ducts suffer seasonal and diurnal variations, especially in the coastal zone where the sharp contrast between land and sea contributes to temporal and spatial variability (Sirkova and Mikhalev, 2003). Similar to this duct phenomena there are many other factors that makes atmosphere around us uncertain and thus affects microwave communication one way or the other. **(Fig. 9)** shows block diagram for the proposed method. This method adds a test signal transmitter and receiver at each base station in order to reduce the effect of ducting on microwave communication. This test signal is used to calculate the time delays and propagation loss on the basis of comparison made between an expected time delay, an expected loss and actual time delay and actual propagation loss. The test signals will be orthogonal to each other or some kind of pseudo random encoded signals to avoid resemblance with other test signal. The test signal receiver may use a correlation receiver to distinguish various test signals from one another. Since the test signals are orthogonal to each other so a single base station test signal transmitter can communicate with multiple test signal receivers of other base stations at the same time. To avoid traffic congestion the test signals are transmitted over idle channel or on signaling channels.

Next to the test signal receiver is the time delay and propagation loss estimator unit that processes the test signal to 'measure' the time delay and propagation losses associated with it which can be done by the use of commercially used software packages Path loss & Connect. Once actual time delay and propagation losses are computed the results are then fed to the comparator unit where a comparison between actual time delay and actual propagation losses and expected time delay and expected propagation losses is made.

Atmospheric models database stores the information of expected time delays and expected propagation losses for test signals. The next unit i.e. the atmospheric duct predicting unit applies the tomography technique on the data provided by the comparator unit to build/generate the profile of the atmosphere to find out the region where atmospheric duct is present. This unit then forwards the output data to antenna positioning unit that positions the antennas at each base station in such a way that the LOS between the corresponding base stations stands. Microwave beam positioning unit shapes the transmission of microwave beam at each base station by arranging the antenna in such a way that main beam/central region of data carrying signal does not enters the ducting region. Applying the above process the possibility of signal getting trapped in ducting layers can be minimized.

4. CONCLUSION

The paper presented the results in the form of simulations for Microwave link optimization carried out for different Microwave links of a renowned telecommunication services provider in Pakistan 'Telenor'. The paper also highlights the influence of a climatic factor known as ducting on microwave communication especially in coastal areas of Pakistan. A brief description of cellular transmission network optimization process is also provided. Furthermore, a technique is proposed for cellular transmission network that could be implemented to avoid communication failure due to atmospheric ducting.

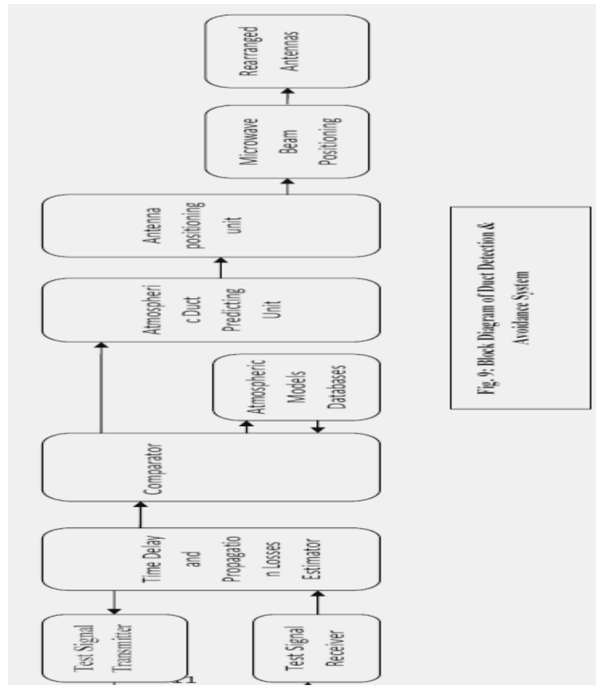

Fig. 9: Block Diagram of Duct Detection & Avoidance System

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