A Study on Frequency Spectrum Utilization of a Microwave Transmission Network to Identify the Hi – Lo Conflicts and to Resolve Them to Improve the Reliability of the Network

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ABSTRACT

In microwave transmission free space point to point communication is used. The frequency band for a microwave communication link is selected according to the hop length. Within a selected Band two frequencies from an available channel is allocated for each link. In this study the main objective was to resolve the Hi – Lo frequency conflicts of a microwave transmission network and then suggest some general guidelines which can be followed to eliminate Hi – Lo conflicts when planning frequencies for microwave transmission networks.

Therefore first, the frequency channels used in the microwave links of the transmission network were studied. By studying the frequency channels, the Hi – Lo conflicts which are already present in the network were identified. With this analysis the hub points which have Hi – Lo conflicts were also identified. Since hubs interconnect several microwave links the resolving of the conflicts was very important. After identifying all the conflicts, the channels of one frequency band were selected. Since 7GHz band had most conflicts it was selected as the network to resolve the conflicts. Then the possible solutions were suggested to resolve the conflicts. Finally considering all the possible situations that can occur when planning frequencies, a set of guidelines and steps that can be used to plan frequencies for microwave transmission links without introducing the Hi – Lo conflicts to the microwave transmission networks were suggested.

KEYWORDS: Frequency Channel, Hi- Lo convention, Interferences, Radiation Patterns, Microwave Transmission

INTRODUCTION

When we consider microwave transmission systems, selecting an appropriate frequency (frequency planning) is one of the most important tasks. Usually the frequency band for a microwave communication link is selected according to the hop length (displacement between the transmitter and the receiver). Within a selected Band a Spot frequency from an available channel will be given by the TRC. Since the total control and the authority of the frequency spectrum is held by the Telecommunication Regulatory Commission (TRC), everybody should get the prior approval to use frequencies.

When we consider microwave transmissions the most used frequency bands are 4GHz, 6GHz, 7GHz, 8GHz, 11GHz, 13GHz, 15GHz, 18GHz, 23GHz and 26GHz.

Each band is divided into two parts called Lo band (low frequencies) and Hi band (high frequencies). Then these are subdivided into several numbers of channels.

When planning a network with microwave links, for a particular link two different transmitting frequencies should be allocated for uplink and downlink for full duplex communication. Therefore each node of a link will transmit in one frequency and receive in another frequency. These two frequencies should have a gap

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between them to avoid interferences among them.

Planning frequencies is therefore a very difficult and challenging task. To avoid interferences, when planning frequencies a special technique called Hi – Lo convention is taken into account. In this method it is recommended that if any node of a network has more than one link, all transmitting frequencies should be selected from one band (Hi or Lo). According to this method if a node is Hi, all transmitting channels should be selected from Hi band. But the problem is that usually in a transmission network there are several Hi – Lo conflicts that affect the quality and the reliability of the network.

But the problem is there is no specific way or guidelines to follow when assigning frequencies. Therefore giving a set of guidelines for planning frequencies will be very useful and valuable.

LITERATURE REVIEW

Behaviour of co-channel interference in fixed wireless cellular systems, such as millimetre-waves Local Multipoint Distribution Service (LMDS), is different compared to what has been established for mobile microwave systems. This is due to utilization of a high-gain antenna for the subscriber (Farahvash, S., Kavehrad, M., (2004)). In this paper, first the analysis of signal-to-interference ratio (*SIR*) is presented for line-of-sight and nearly line-of-sight LMDS architecture. In this analysis, the effects of precipitation and foliage attenuation and depolarization have been considered. These two parameters have negligible effect on the microwave mobile systems but in millimetre - wave range are among the most important factors in the link budget. To mitigate the fading due to shadowing by buildings and trees, a highly overlapped architecture and macro-diversity are proposed. After analysis of downlink *SIR* in previously proposed cellular systems, a cellular architecture is proposed based on polarization interleaving and frequency segmentation which has a much higher *SIR* yield. The statistical assessment of *SIR* is accomplished by assuming lognormal distribution for the received signals.

This study was primarily intended to explore concerns raised in the record of the Commission's proceeding *In the Matter of Creation of Low Power Radio Service*, MM Docket No. 99-25, regarding the potential impact on the Radio Reading Service of eliminating third adjacent channel interference protections for 10 watt and 100 Low Power FM (LPFM) stations. The study was conducted using a sample of fourteen FM broadcast SCA receivers provided by National Public Radio (NPR). Thirteen of these receivers were tested for adjacent-channel and co channel interference performance; the remaining receiver was deemed not testable because of severe main channel bleed through problems. Because of the small sample size, the test results presented herein were not extrapolated to the general receiver population. (Means, D. L., (2000))

Signal to Interference ratio (S / I) calculations for corner excited cellular communication systems based on median mobile–to–base and base-to-mobile signal powers for co channel interference and immediately adjacent as well as non-immediately adjacent channel interference is presented. The mathematical model includes most related system parameters such as cluster size, filter characteristics, propagation exponent, tier coverage and directional antenna front-to-back ratio. Both mobile-to-base and base-to-mobile cellular communications are investigated. The calculated results proved that the effect of adjacent channel interference compared to co channel interference cannot be ignored in the general and may have severe performance degradation under some specific operating environments, for particular system architecture. (Yousef, G., Jaafreh, E. I., (2000)) The GSM recommendations state that reference interference will be achieved at a C/I margin of 9 dB for co-channel interference and that the margin is -9 dB C/I for adjacent channel interference. The results of measurements show that under simulated Rayleigh fading conditions, this is not adequate and a higher margin is needed. Furthermore, the results show that due to the channel coding process and interleaving, the statistical measure of signal quality is dependent on the speed of the mobile. The results also show that the reception quality parameter used in the GSM standard for many of the important decision such as handovers and power control is also dependent on speed and is not a true reflection of the speech quality. (El-Saigh, A.I., Macario, R.C.V., (1996)

In an electromagnetic transmitting or receiving communications system with multiple polarization capability, in the transmit mode an input signal is divided between two signal processing channels which feed a dual mode radiation element for exciting orthogonal polarizations. The signals in the two channels are shifted in phase relative to one another prior to power amplification. In the receive mode first and second channels connected to the dual mode element process received signals of certain polarizations governed by phase shifting the channel signals relative to one another, the phase shifting taking place after amplification. Various parallel channels may be incorporated in the receive mode of operation to simultaneous process signals of the same, or other polarizations and when incorporated within an array having electronic beam steering, the polarization selection may at each respective channel be combined with the beam steering function. (Henry C., (1976))

METHODOLOGY

The planning of microwave transmission links is a complex process, because the assigning of frequencies for links should be done carefully. Therefore first the process of planning frequencies for microwave transmission links was studied. Since the selected research problem is due to the behavior of microwave signals, then the microwave signals and their behavior and the radiation patterns of the antennas was studied.

The problems that occur due to the presence of Hi – Lo frequency conflicts in the microwave transmission network were identified. This was very important because the presence of these conflicts may not a problem itself sometimes. But it may give some other problems when the network is expanding. Therefore, how the interferences can occur due to the Hi - Lo conflicts was analyzed.

After having a good understanding of the problem the microwave network of the organization was studied. Since the network of the organization was very large and complex, the studying of the entire network was difficult. Therefore, to do this research only the 7 GHz band was selected, because it was one of the most used band and high capacity 7GHz links only have 4 sub channels. Since there are only 4 sub channels the planning of frequencies while avoiding core channel and adjacent channel interferences is very difficult.

Then all the information related to all 7GHz links was collected from the organizational databases. Then the frequency channels used for each link in each Base station was analyzed to identify the Hi – Lo frequency conflicts. After having a good understanding on the conflicts already present in the network, the links were plotted in a map to identify the actual locations of the Base Stations and the network structure. Because when resolving the Hi – Lo conflicts the physical locations and the network structure is very important.

After plotting the 7 GHz network, the Hi – Lo conflicts was studied and marked on the map. Then considering each and every situation the conflicts were resolved. The resolving of conflicts was done by considering each node in the network. But there arises some difficulties, because this network is in use and therefore some changes were not possible.

After having a good experience on how Hi – Lo conflicts are occur and how to resolve them, a set of guidelines were suggested for planning frequencies without generating Hi – Lo frequency conflicts.

DATA COLLECTION AND ANALYSIS

The microwave communication links are full duplex communication links. Therefore they can transmit and receive at the same time. To achieve this two frequency channels are assigned for each microwave link. Therefore the station at one end of the link transmits in one frequency (f1) and receives in other frequency (f2) and wise versa in the other end (transmit in f2 and receive in f1) as shown in below figure.

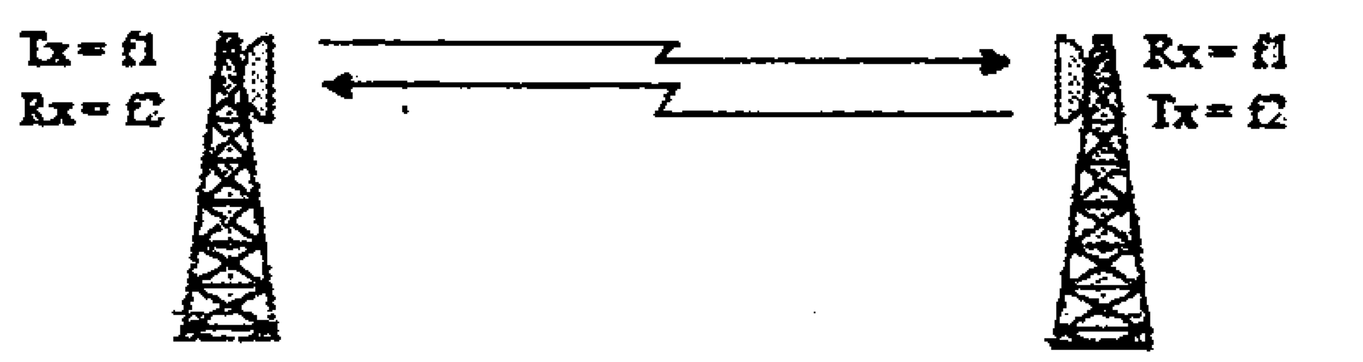

Figure 1. Full duplex channels

When setting up the frequency channels, two frequency channels are bundled together so that they can be used for full duplex channels without interferences. Therefore first the frequency band is divided in to two parts called Hi band and Lo band. And then each portion is subdivided into channels. Then two frequency channels one from the Hi band and the other from the Lo band are bundled together.

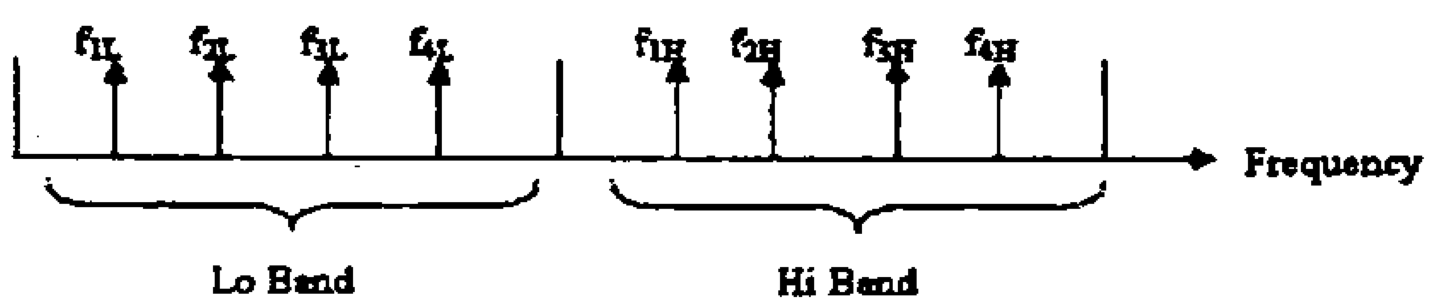

Figure 2. Frequency channels

According to the Hi – Lo frequency convention, all the transmitting frequencies of a Base Station should be from either Hi band or Lo band. Hi – Lo frequency conflicts are not allowed. If there are any Hi – Lo frequency conflicts the links may subjected to adjacent channel interferences. Although the directional antennas are used for point to point line of sight microwave communication, the radiations of those antennas are not exactly directional. The radiation pattern consists of back lobes and side lobes. These additional lobes have a very small strength. When there are more than one microwave link in the same tower, those back lobes and side lobes interfere the receiving signals of other links. Since the receiving signal is a very low strength signal the interference from these side lobes is very high and receiver have difficulties when identifying the correct signal. To avoid this, the Hi – Lo frequency conflicts should be resolved from the network. Then the frequencies of the different links have a considerable gap between them and therefore, each receiver can distinguish the specific receiving signal.

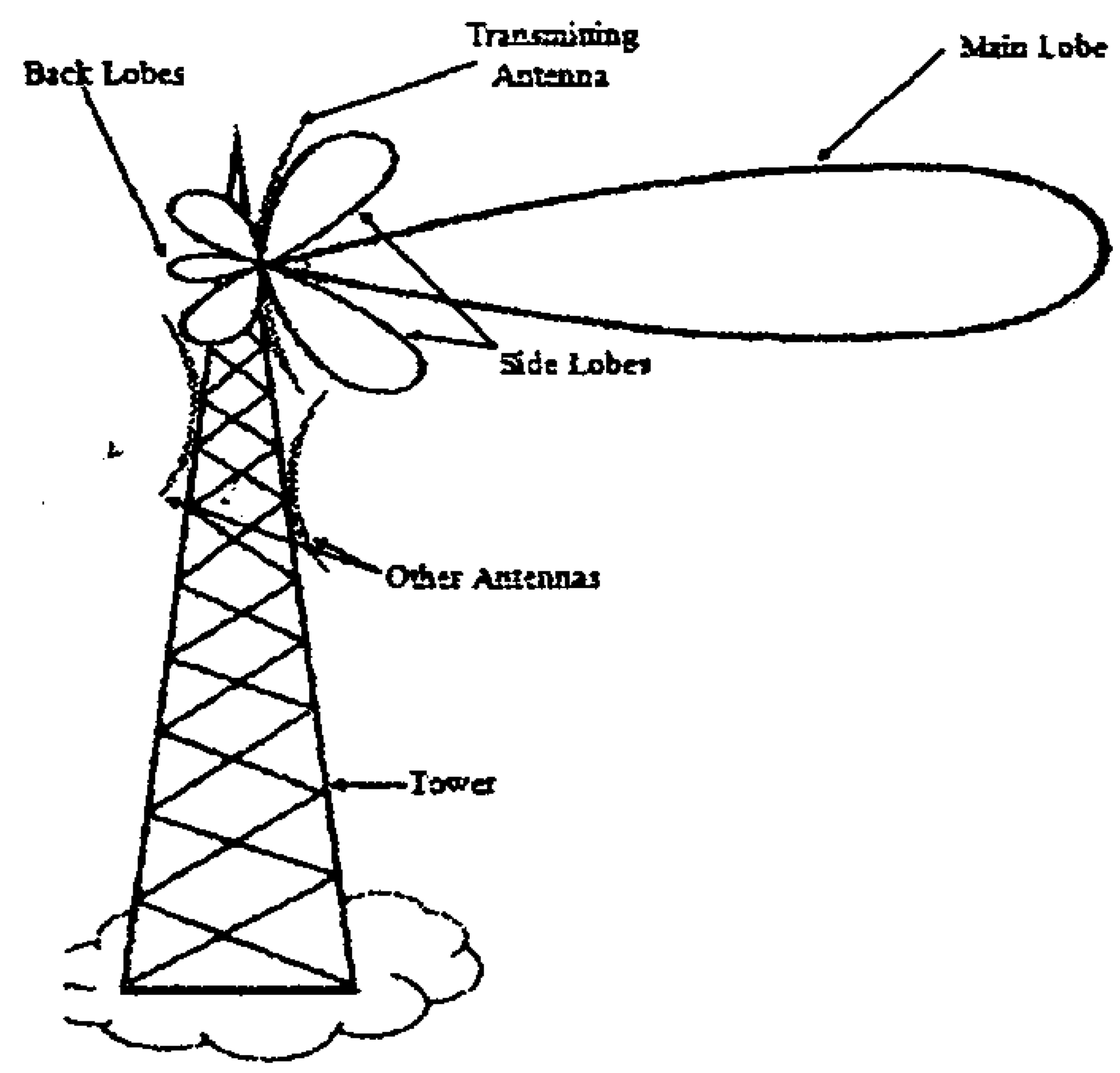

Figure 3. Interference between different links in the same tower

Each microwave frequency band consists of number of frequency channels. Only the 7GHz frequency band was considered in this study. There are only 4 frequency channels (28 MHz channel bandwidth) in the 7 GHz microwave frequency band. Each channel consists of 2 frequency channels.

Table 1. Channel Frequencies of 7GHz band

Channel Frequencies (MHz)	
Lo Channel	**Hi Channel**
7149	7310
7177	7338
7261	7422
7233	7394

The organizational databases consist of all the information related to each and every microwave transmission links of the network.

They consist of frequencies, capacity, polarization, configuration and etc. Following table shows a part of the information collected from the organizational databases. But some information was encoded to protect the organizational confidentiality.

When planning frequencies for transmissions, the same frequency channel or adjacent channels cannot be reuse in the same area. Because the channels will have co channel interference and adjacent channel interference, if they are used in the same area. Therefore the Telecommunication Regularity Commission provides a list of information which provides the necessary data related to the frequency channels in use and where they were used. When planning frequencies this information was considered. The analysis of the data was started by categorizing the microwave links according to the frequency band used by them. Once all the links were categorized the frequency bands, they were again listed according to the nodes they were connected. At the end of this process, the links connected each node and their frequencies were observed as the result. This was very important because the Hi – Lo conflicts had to be analyzed with respect to each node of the network. At end of this process it was found that the most important and critical frequency band is the 7GHz band. Therefore, only the 7GHz frequency band was selected for further study.

Then all the 7GHz links were listed according to the nodes they were connected and then the Hi – Lo status of their transmitting frequencies were studied. The table 5.4 shows a part of the analyzed frequencies. Then the nodes which have Hi – Lo frequency conflicts were identified. Table 5.4 shows the status of each node and it shows the nodes which have Hi / Lo frequency conflicts.

After analyzing all the nodes and observing the status of all nodes, the Hi / Lo frequency conflicts were studied to identify the possible changes that can be made to resolve the conflicts in the network. When resolving the Hi / Lo conflicts, the structure of the network is very important. Therefore the links were plotted by considering the locations each node.

When studying the structure of the network, it consists of several isolated small networks. Therefore conflicts were resolved by considering those small networks as separate networks. This helped reduce the complexity of the network. Because it was very difficult to resolve the conflicts, when there are with large network rings.

When changing the frequencies of the links, the data observed from the TRC was also considered to find out the available frequency channels for that particular area. Because, if a changed frequency is already being used by another network, the TRC do not give the permission to use that frequency. Since the TRC have the full control and authority of using the frequency spectrum within Sri Lanka, the approval of the TRC is necessary for the frequencies.

When the frequencies were studied, some of the nodes do not have Hi - Lo conflicts, their all transmitting frequencies are either Lo or Hi. But some nodes consist of both Hi and Lo transmitting frequencies. To remove the conflicts all transmitting frequencies of a node should be changed to either Hi or Lo.

In some nodes the resolving can be done by simply interchanging the two frequencies used by the transmitting and receiving channels. But when the network is complex this interchanges may give rise to more and more Hi / Lo conflicts in other nodes which connected to them. Therefore the structure was also considered when interchanging the frequencies.

In some cases the polarization of the microwave links were changed. Therefore the vertical polarized signals and horizontal polarized signal can have different Hi / Lo status in the same node. Because of the different polarization the interferences are eliminated. But the problem of using the horizontal polarization is, the effect of rain fading is higher for horizontal polarized signals.

RESULTS AND DISCUSSION

The problem of Hi – Lo frequency conflicts in a network can occur due to several reasons. Therefore the solutions for this problem depend on the situation and the place where the problem has occurred. Therefore the following set of solutions can be used in different ways by considering specific situations. The solutions are given as a set of ongoing steps. If a conflict cannot be solved with the first step, the next step should be considered.

- Interchange the frequency channels used by the transmitting and receiving channels.
- Use a different frequency channel with same channel bandwidth.
- Use dual polarization. Use one polarization for frequencies in Hi band and another polarization for frequencies in the Lo band.
- Use a different channel frequency channel with different bandwidth.
- Change the frequency band by changing the hop length.

Above steps can be considered for resolving the Hi – Lo conflicts already present in the transmission network. The other important thing is eliminating the introducing of new Hi – Lo conflicts to the network. Following are some of the important guidelines that should be considered when planning new microwave transmission links.

- Analyze and define the status of each node in the network either Hi or Lo for each frequency band. Different frequency bands may have different status in the same node. If there are both Hi and Lo frequencies select the band with most number of links.
- When planning new links always assign frequencies by considering the pre defined status of the nodes.
- Avoid network rings with odd number of links. Odd numbered rings will always introduce new conflicts.
- Try to plan the network with a set of regional sub networks than planning the network as a large complex network.
- Try to avoid network rings in the same frequency band. Same frequency band rings will give problems when planning future links.

CONCLUSION

The frequency spectrum is a limited and scare resource. Therefore the frequency spectrum should be use very carefully. Otherwise all the users will face critical problems. Therefore all operators should accept and follow the approvals and conditions of the TRC. On the other hand as the authorized and control body, the TRC should provide their help to resolve the problems faced by the network operators.

Although the network planning was done carefully to minimize the interferences, sometimes TRC do not give the permissions to use the requested frequencies. This introduces more difficulties for the uses. Therefore the TRC should discuss the matters with the network operators.

There are several numbers of organizations that use the frequency spectrum for businesses such as mobile network operators, radio channel operators and television channel operators. Because of the higher competence, organizations do not obey the guidance of the TRC and other governing bodies. Also they do not like to give the information for external bodies, because they do not trust others. But it is beneficial for all of them if they have some kind of an agreement on how they use the frequencies. This will help to minimize the unexpected interferences and noises.

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