Interference Calculation Rules

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Frequency planning and interference calculations - Basic principles

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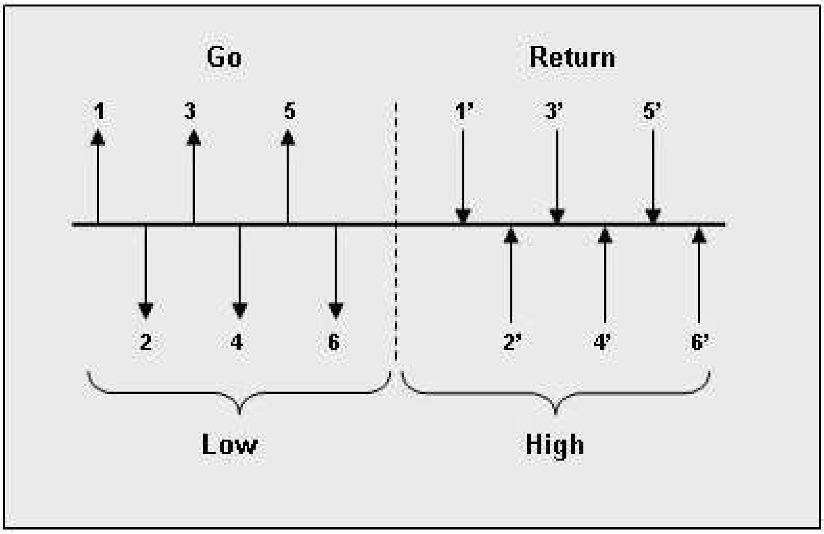
Introduction

Frequency planning is a delicate operation, because an efficient use of the Spectrum is considered of primary importance in an environment of frequency congestion.
Few simple rules help to reduce the risks of the interferences and to follow strictly these procedures represents the most efficient way to optimize the Spectrum utilization.
Even if all the possible precautions are taken, risks of interferences (intra or inter-system type) always exist. It is important to evaluate correctly the different types of interference, in order to avoid both excessive degradations and over-conservative engineering.

Frequency Planning

High/Low rule:

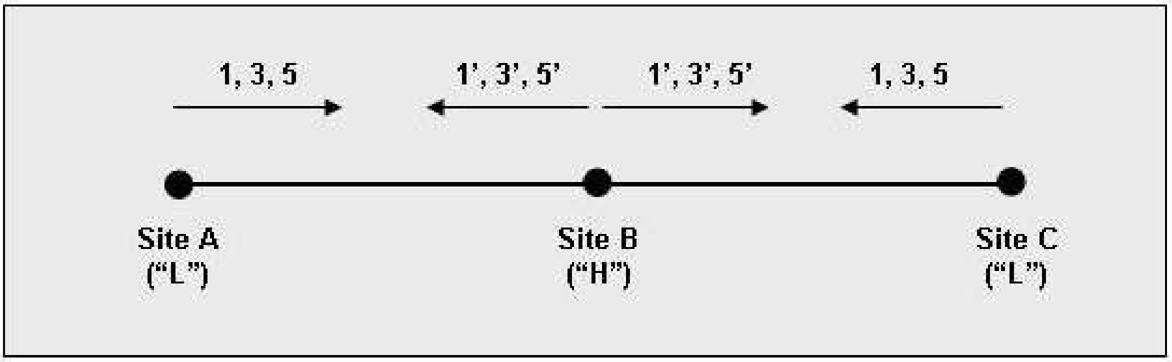
The **first basic** rule for a correct frequency planning is the so called "high/low" rule
Each frequency band is normally divided into two identical parts, each containing all go (Tx) or return (Rx) channels.



This trick permits to maintain under control the interferences among channels in the same hop. As consequence of that, one station can be defined as "high (or low)" and the other the opposite "low (or "high")", i.e. each terminal transmits (or receives) channels belonging only to the same semi-band.

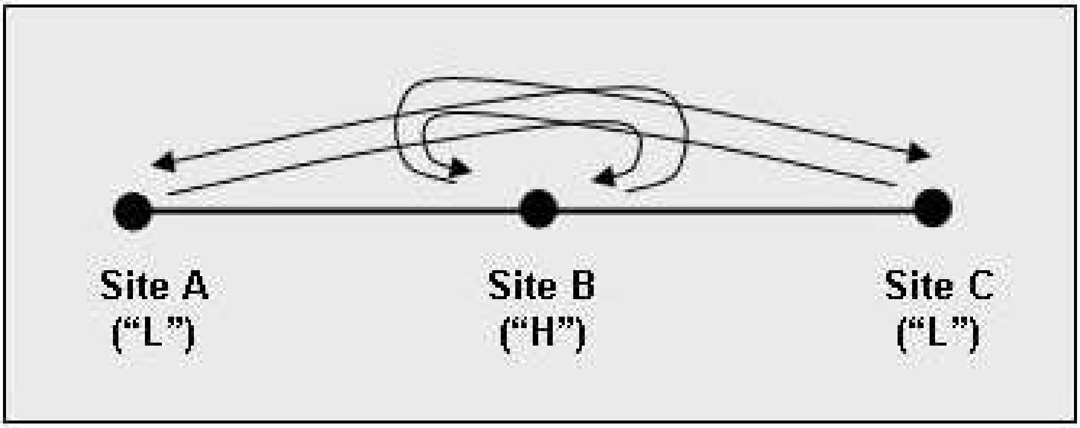
In case of a new cascade hop (one station in common), the common station must be coherent, i.e. each station can be named as “high” or “low” (where “high” or “low” refers to the TX frequencies)

This means that a common station transmits in all the diverging directions from the node in one of the two semi-bands and, consequently, receives channels in the opposite semi-band.



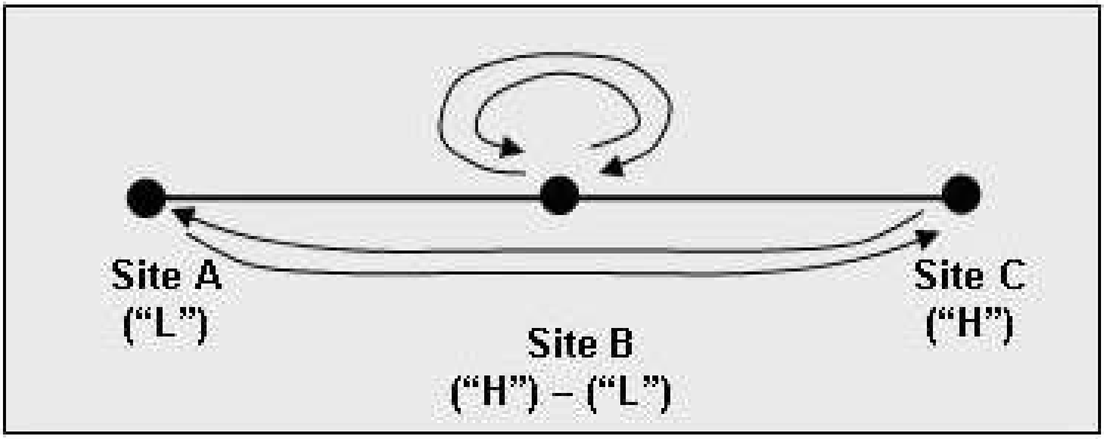
This arrangement must be considered mandatory. Each planning must be done having this rule well clear in mind. A well engineered radio network should follow strictly this rule.

Which are the risks in case of non-compliance with the rule? Let us consider the regime of interferences in case of High/Low rule satisfied.



The possible interferences come from the far end terminal. Local interferences are not possible because the channels Transmitted and Received in the two directions belong to different semi-bands.
Consequence of that is the possibility to calculate the overall protections basing the procedure to the well-known concepts of Gain, Free Space Attenuation and Antenna Protection, all valid only in Far Field conditions.

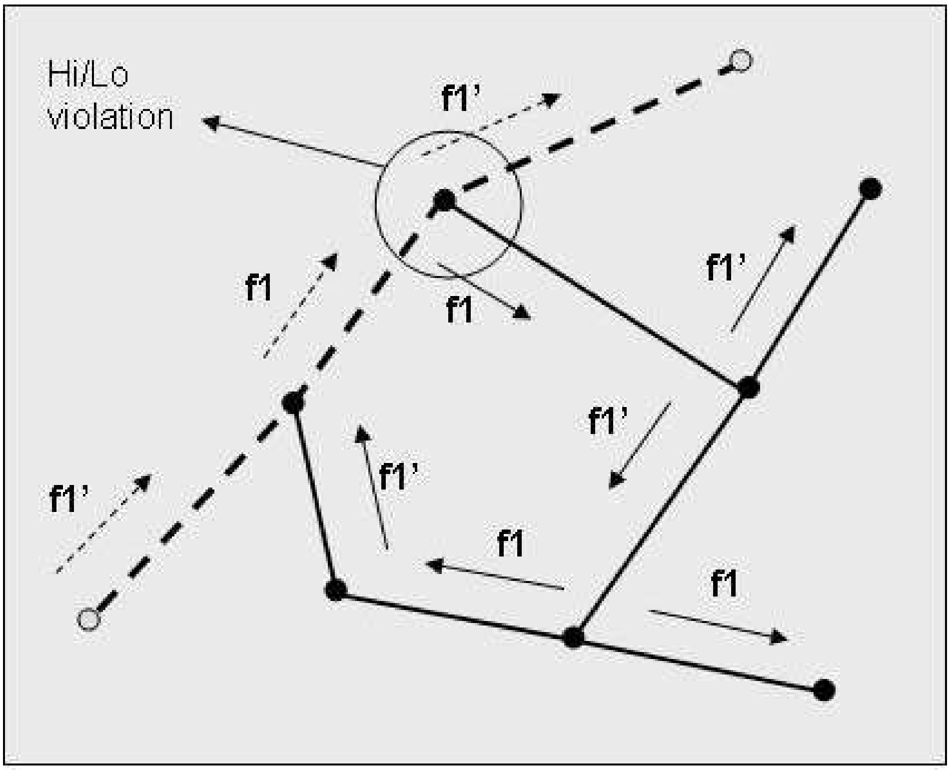
In case of violation of the high/low rule, the interference scheme becomes as following:



To the risk of direct interferences Site A – Site C (which can be considered in the traditional way of calculating the overall protection), it is necessary to add an unpredictable effect of local interferences in the near field area of site B.

The basic concepts used above are no longer valid in near field conditions and therefore it becomes quite impossible to anticipate the effects of the interferences.

It is almost always possible to avoid such a condition (at least in case of frequency arrangements of completely new networks).
Unfortunately, there are cases where this situation is unavoidable.
Let us suppose to have to expand an existing network with limitations on the number of frequencies available.
The classical situation is the closure of a ring.



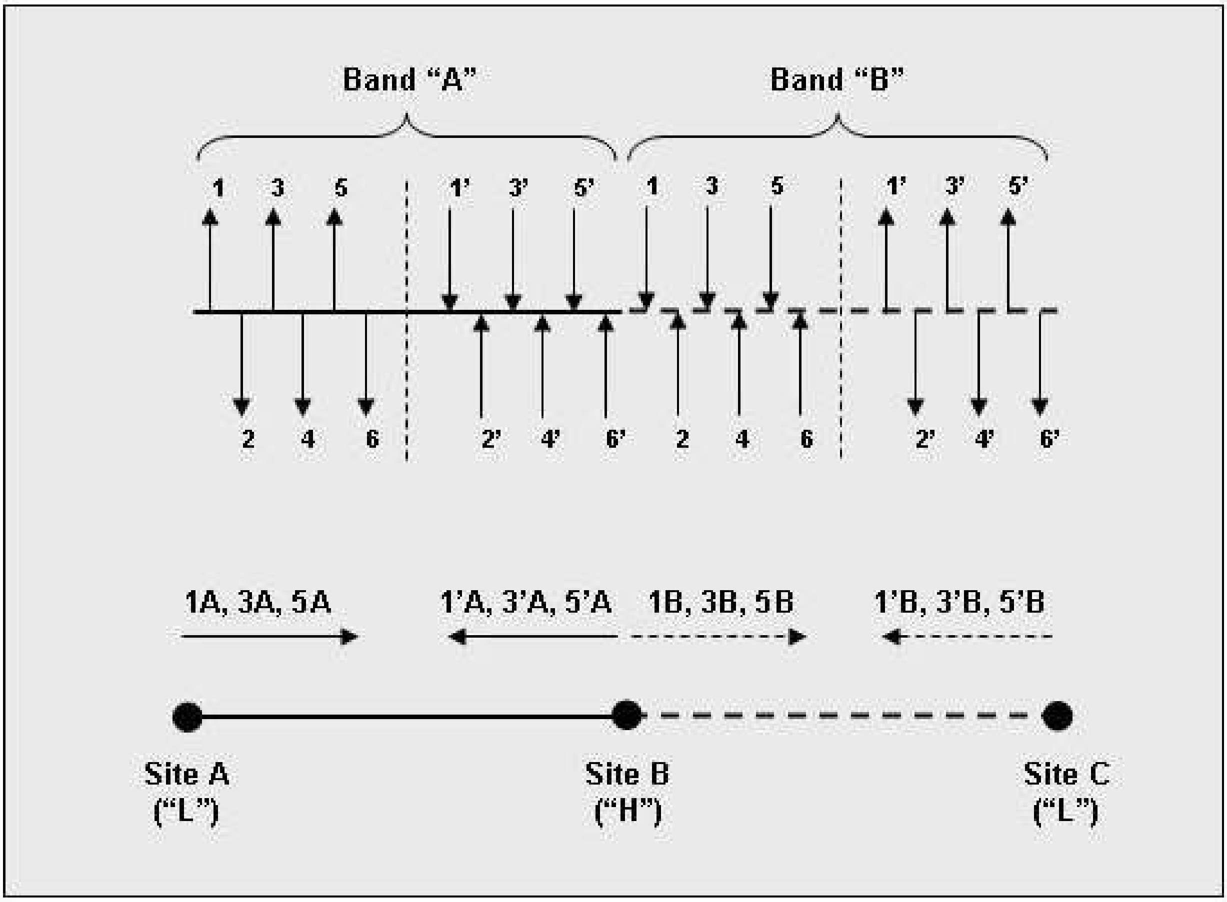
Three new links (dotted lines) have to connect two new stations through two stations of the existing network. It is immediate that, in case of utilization of the same frequency band, the closure of the ring with an odd number of sides brings forth to a High/Low violation in one station.

In this case it will be necessary to change frequency band or, if not possible, to space the channels in the various directions as much as possible, considering the NFD values of the equipment. A high value of protection, delivered by the overall selectivity of the Receiver, can provide enough margins against unwanted unpredictable behaviours of the near-field interferences.

Planning with adjacent bands

To solve cases like the one above, or for many other reasons, it could happen that the bands used on two adjacent links are different, but contiguous.

The High/Low rule changes and it will be safer to apparently violate the rule (it is not a real violation, because the bands are different).
The figure below will explain the situation.
By using this solution, the channels transmitted (or received) in two directions using adjacent bands belong to contiguous (or distant) semi-bands and not to a mixed situation.



If the two bands are not contiguous the problem does not exist. The distance between the two closest channels will be high enough to avoid interference problems.

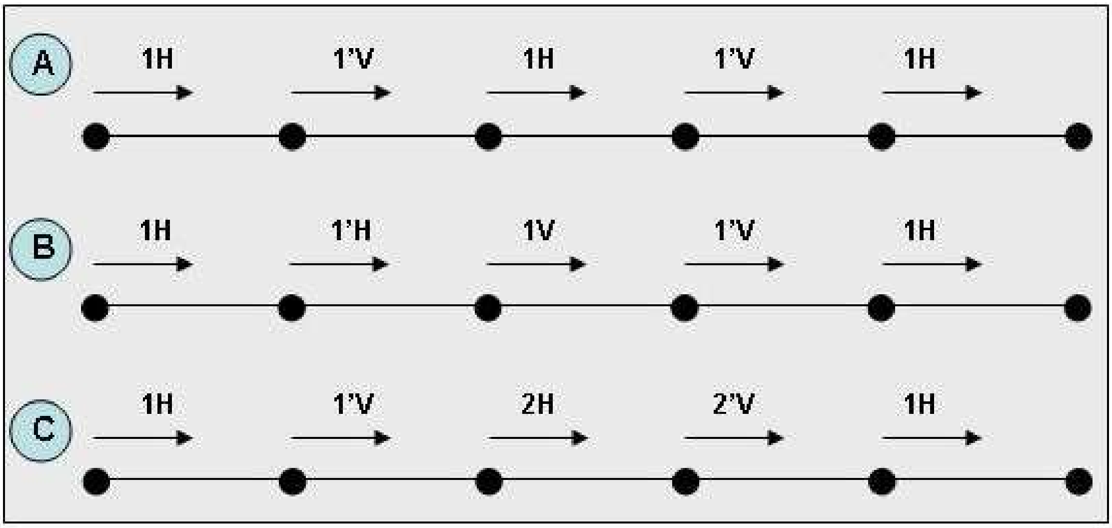
Over-reach Interferences

The general principle which leads any frequency planning is to transfer as much as possible information by using the minimum number of channels.
Each channel, if possible, should be repeated over contiguous links in order to reduce the number of channels involved in any radio network.
This will be seen with favour by any Administration and helps to reduce risks of interferences among Networks of different Operators.

The case (A) below represents the typical case of frequency repetition (only the “go (Tx)” channels are drawn). The same channel is repeated and the polarizations are alternated in order to increase the antenna protection. Of course, the success of this arrangement depends on the angle between the directions, the antenna types etc.
In general, this arrangement can be used with angles higher than 90/100°, but a complete interference study must be always done.

Looking at the figure, it appears that this arrangement leads to a potentially dangerous interference, i.e. the channel transmitted from the first station is the same in frequency and polarization of the signal received by the fourth station.
This is the so called “over-reach” interference.

In a “zigzag” configuration the angles between the direction of the interference and the alignment of the antennas are normally enough to protect, but could happen that these angles become very small in particular network configurations.
Likely, the visibility between station 1 and 4 does not exist and therefore this risk could be seen as apparent, but it is very dangerous to simplify.
The interference calculations must be ruled by a conservative approach. The risk of bad operation due to interference is always very high and non-justified optimism could make fruitless any expensive solutions adopted to improve the quality of the systems (like space diversity, high towers etc.).
The conservative approach suggests to test the visibility of the interference under extreme visibility conditions (K= infinite).



This means that the simple curvature of the earth surface cannot be used as an obstruction (in k=infinite situation, the ray runs parallel to the surface) and real obstacles must exist along the over-reach direction.

Solution (B) represents a small improvement. The crossing of the polarization each three hops will increase the protection. Nevertheless, this solution is normally not enough, in case of full alignment and full visibility.

Solution (C) solves the problem, but requires another frequency.

It is not possible to define general rules in order to anticipate the possibility of such interference, but some points can be underlined:

1) Longer are the hops, lower is the probability of over-reach, since the direct path likely will be obstructed.
2) Higher is the frequency band lower is the probability of over-reach, since the antenna protection increases (even if the reduction in the hop length could act against).
3) Bigger are the angles among the directions lower is the probability of over-reach, since the antenna protections increase.

Interference calculation procedure

In case of a well engineered Radio Network (i.e. absence of high-low violations), three main types of interference mechanisms can be individuated:

- **a) Non-correlated interferences**
- **b) Partially correlated interferences**
- **c) Correlated interferences**

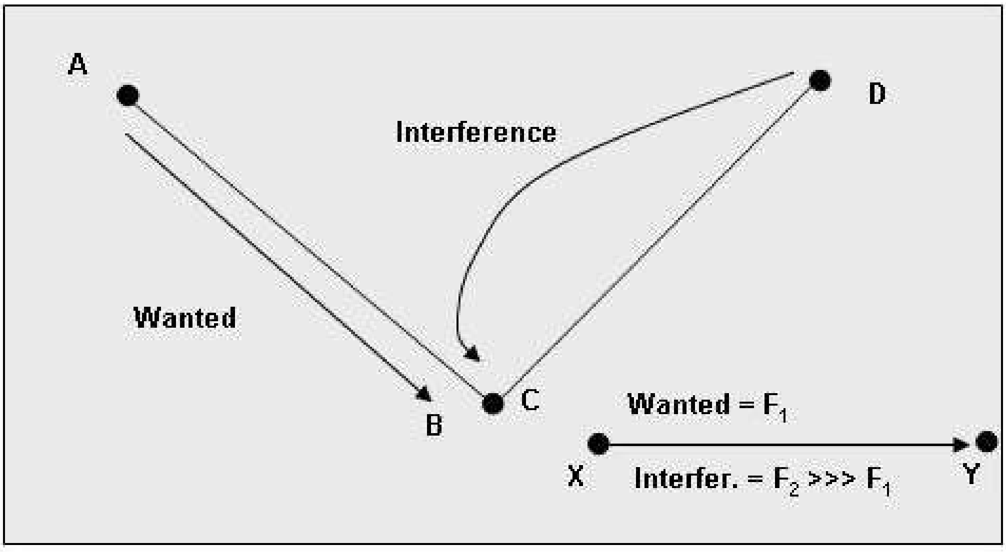
The study of the three items follows different procedures and useful simplifications are usually possible.

a) Non-correlated interferences

This first case represents the normal interference case and happens when the fading activity on the Wanted hop (C) is not correlated with the Interfering one (I).

Normally this case relates to wanted signals following different hops in respect to the interfering ones, but can be applied also to signals following the same path but “distant” in terms of probability of fading simultaneity (i.e. C and I very far in frequency).

Due to the physical characteristics of the very deep fading considered in the multipath analysis, a realistic assumption is to consider that only one fading exists at instant t_0 in the area and, conservatively, insists on the wanted hop, whilst the interfering one operates at full power.



This scenario is normally considered in any interference calculation procedure and represents the most common cause of threshold degradations.

It is normal practice not to consider in the calculation the interference caused by a channel very far in frequency since the NFD protection assumes such a high value due to the response of the RX filters (total selectivity) that the interference level is usually negligible.

Normally the NFD at two or three channel distance is so high to allow not considering the case.

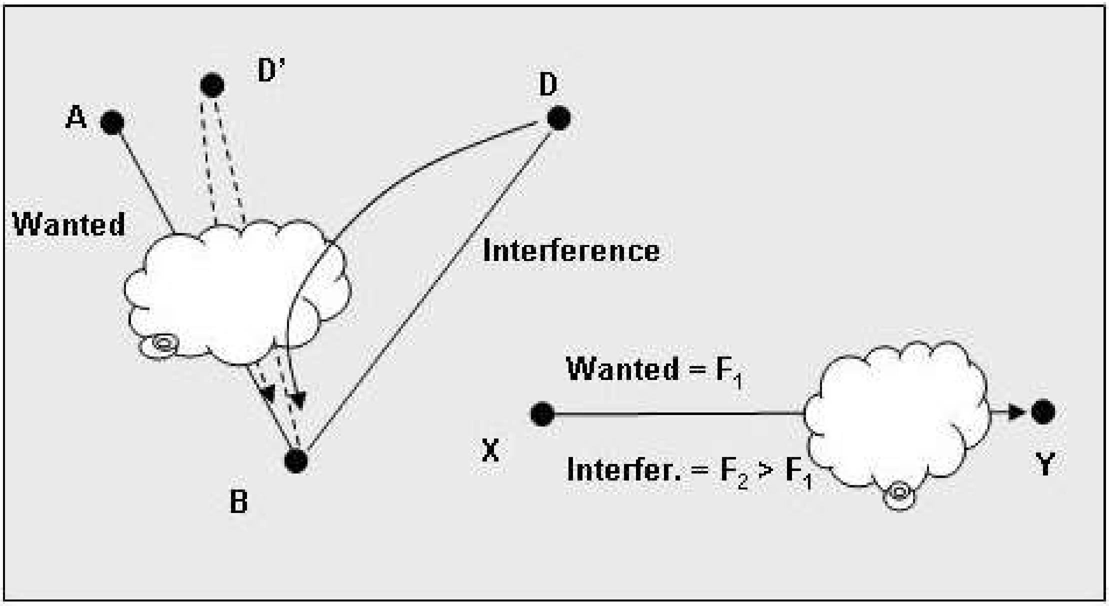
In conclusion only the spatially uncorrelated interferences must be considered, resulting in a first simplification of the procedure.

In case of operation with Radio Systems having the ATPC function, the activation of the function permits to highly reduce the effect of the interferences.
Since the assumption is to have the deep fading on the wanted hop and no fading on the interfering ones, it is assumed that the TX amplifiers of the Wanted hop are in high power condition, whilst the ones of the interfering hops operate at low power, introducing an improvement in term of C/I equal to the ATPC range.

A further consideration must be done considering the causes of fading.
It is well known that both clear air phenomena and atmospheric precipitations can lead to outage periods. The fading depth induced by multipath and rain can result in the same amount of attenuation, but the time duration and the spatial extension of the phenomena are very different.
Multipath produces very deep fading very short in time and with very high spatial decorrelation whilst rain is also cause of deep fading but with different time variability and extended over wide iso-attenuation area (few km).

Therefore, the above considerations on the interference mechanisms, valid for clear air environment, must be revised in case of operations at frequencies where the rain phenomena are no longer negligible.

The classic interference case could be treated exactly as in the clear air condition. Of course, by reducing the angle between the two directions leads to a gray area where the not correlated conservative approach becomes too much conservative (since a deep rain area extends over some square km and therefore both wanted and interference signals suffer of the same attenuations).



Results from various field trials are making the base of a future recommended procedure, and presently methods to consider the improvement effect of the rain induced correlation exist, but cannot be considered stable and fully reliable. The present release of ITU P. 530 recommendation contains a first procedure to consider such an improvement.

A reasonable procedure is to follow the conservative calculation and to judge case by case, eventually by forcing from outside other figures instead of the results coming from the automatic interference calculation procedure.

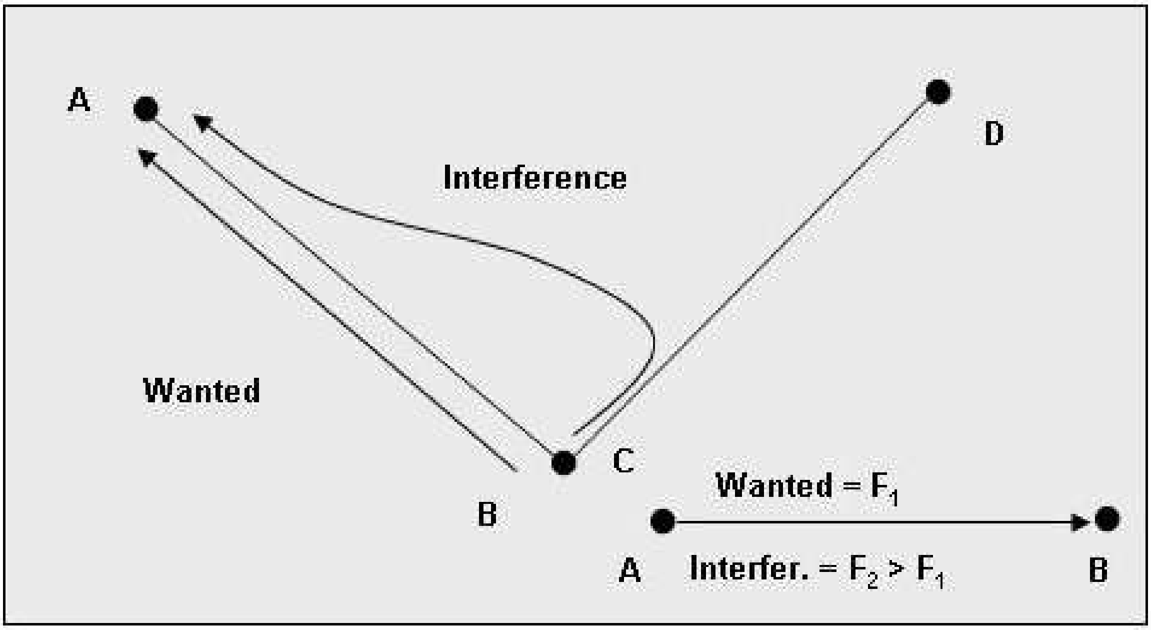
Conversely the second case of interference (i.e. the effect of an interfering channel far from the wanted one) is very clear: the interference does not exist at all since the rain phenomenon covers a band usually wider than the frequency band used and all the channels suffer simultaneously the same attenuation.

b) Partially correlated interferences

When Wanted and Interfering signals follow the same route, different degrees of correlations can be individuated.
The correlation factor can vary from 1 when both signals operate on the same frequency and the antennas in B and C are at the same elevation to other values dependent on frequency distance and elevation.

There are basically three different approaches to consider this type of interference when the multipath phenomenon is considered.

1. **Conservative approach** – the interference is treated exactly as the case a)
2. **Optimistic approach** – The interference is not considered at all
3. **Realistic approach** – The interference is considered as the case a), but a certain "protection" is arbitrarily added to the interference.



The item 3) should be logically preferred, but the definition of the “protection” quantity (10 dB or more or anything else?) is not easily achievable since no data are available from the literature.
In any case any automatic procedure should apply this figure only to the interferences operating on the same frequency of the wanted signal and only when the height of the two Tx antenna (B and C) are approximately the same.

For this reason, the approach 1) (conservative approach) should be chosen.

In case of automatic calculation, particular attention should be paid to the results. If this interference governs the degradation of the threshold, a case by case decision to consider or not the case is required.

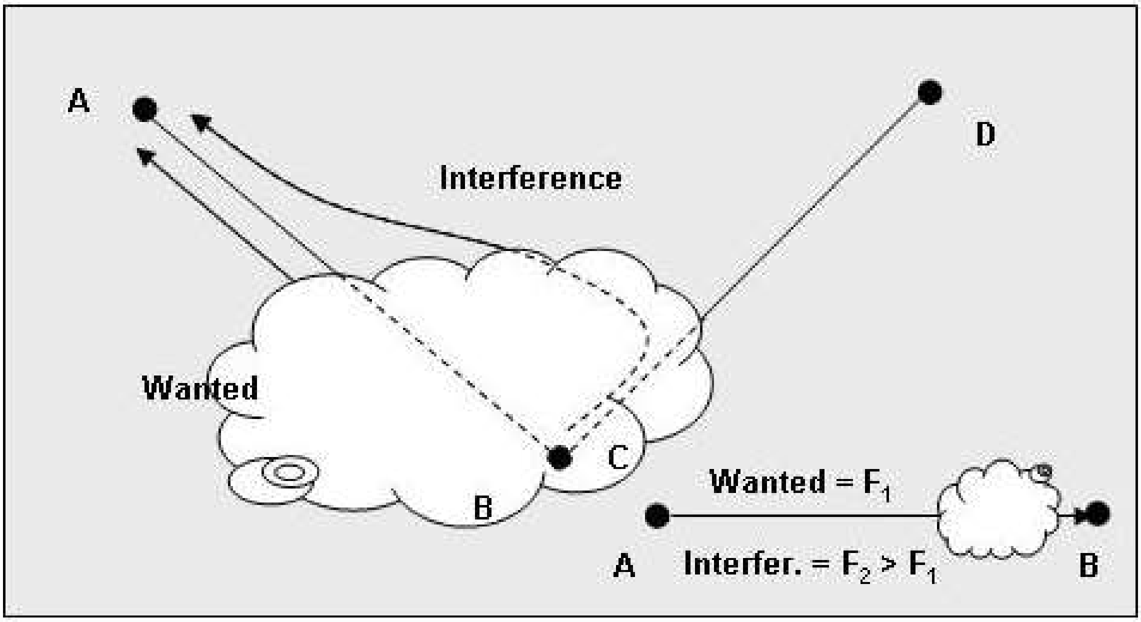
To this family of partially correlated interferences belongs also the effect of a non-adjacent channel spaced two or three channels operating on the same hop of the wanted signal. Again, as in the previous point, the value of NFD is normally sufficiently high to allow the simplification to not consider the case.

When atmospheric phenomena like rain are considered, the above simplification is no longer valid and a different approach should be advisable.

There are no reasons to follow the conservative approach, since rain normally extends over an area of few km.

For sure Interference and Wanted signals suffer simultaneously of the same amount of attenuation.

Therefore, to follow the uncorrelated approach can lead to over conservative results without any physical justification.



An automatic procedure should be able to recognize these cases and not to consider them when rain calculation procedure is in progress.

Fully correlated interferences

Following the above statements, Point c) should be regarded as a particular case of point b) and the above considerations are valid.

Actually, one situation is different from the above. It is the case of interferences caused by the same channel in different polarization or the adjacent channel in the same or in the cross polarization on the same radio hop.
It was proven that the correlation is almost complete and therefore another simplification is permitted.

Co-channel interference

Both signals experience the same attenuation but the XPD value degrades according to the depth of the phenomenon.
The reduction of XPD, following well-known laws, introduces interference and consequent threshold degradation. This worsening should be considered together with other degradations caused by interferences to compute the overall degradation.

Adjacent channel interference

The distance of the adjacent channel (normally 40 MHz max.) is not enough to completely de-correlate the fading on both channels. The application of the formula to calculate the improvement due to a frequency diversity configuration with ΔF=40 MHz leads to a correlation factor usually higher than 0.99.

Considering also a normal value of NFD at the adjacent channel (around 20/30 dB), It will be reasonable not to consider this case of interference.

Conclusion

- The effect of any adjacent channel in the same radio hop of the wanted one can be neglected.
- The effect of the co-channel signal on the opposite polarization must be considered following the procedure “co-channel interference”
- The effect of pure un-correlated interferences (case a) must be considered following the traditional procedure
- The effects of “un-correlated type” interferences in rain environment must be considered in principle following the traditional procedure. Particular cases (e.g. low angle between directions) must be considered case by case.

The effect of partially correlated interferences will be considered conservatively like the un-correlated ones in multipath environment, whilst will be neglected in non-clear air situation.

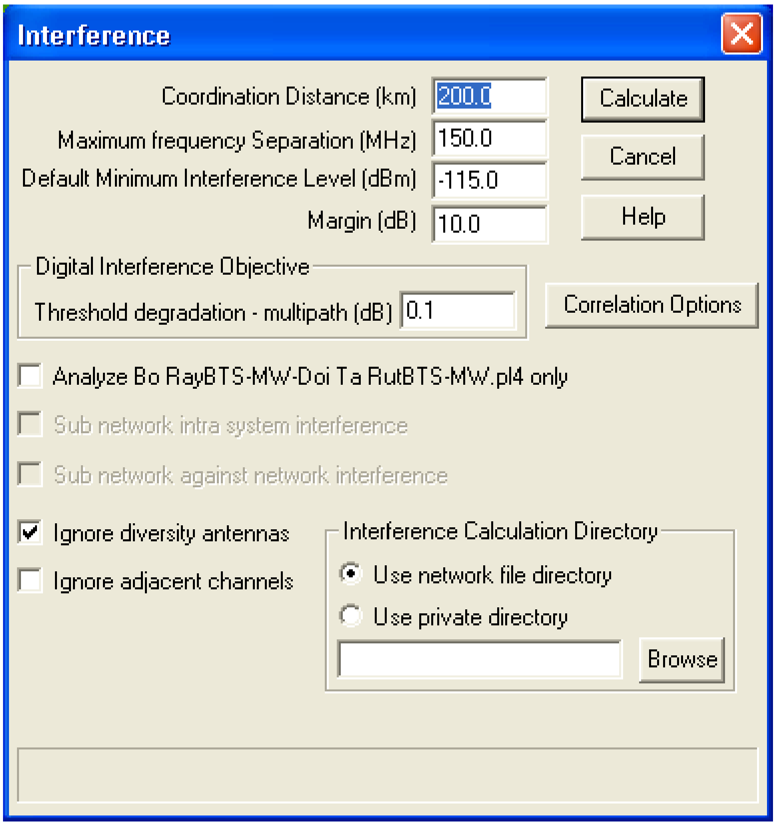
Interference calculations are normally carried out by means of the relevant applications of “Pathloss” software tool.

Pathloss calculates the effect of any interference in term of degradation of the Threshold and this degradation can be associated to the hop calculations to compute the real expected behavior of any radio path.

To consider the above considerations on the correlation among signals and interferences, easy operations inside few panels of Pathloss are required.

The first procedure defines the general parameters considered during any interference calculation. The setting remains whenever the program is reopened.

Panel “Interference”



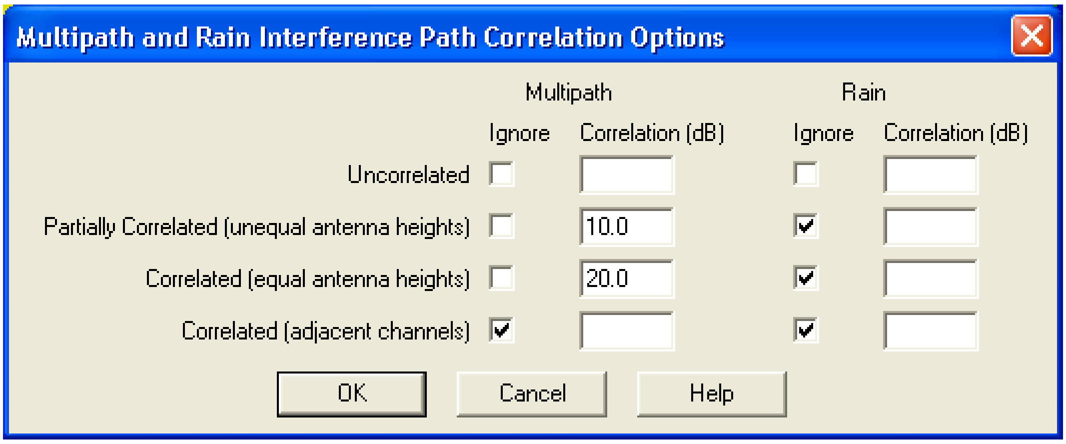
The settings should be fixed as they appear in the panel. These are the typical values for the interference calculation.

The following ones have particular meaning:

- **<u>Coordination Distance</u>**: this is the maximum victim-interfering distance above which the interference case is not calculated
- **<u>Maximum freq separation</u>**: this is the maximum frequency spacing between victim RX freq and interfering transmitter above which the interference is not calculated
- **<u>Threshold degradation – Multipath</u>**: is the total degradation margin for each RX antenna below which the interference is not considered
  (Typical figures for this value are 0.1÷1 dB)
- **<u>Ignore diversity antenna</u>**: this option ignores in the calculation the RX frequencies related only to DIVERSITY RX antennas.

Do not flag the field "ignore adjacent channel", because this option is not related to the correlation/non-correlation matter, but simply all frequency channels will be ignored except the first one. This option could be used in case of quick preliminary calculations, but we never use it.

By pushing the button "Correlation Options", the second panel will open



Make sure that the values in Correlation Options window are as appear above.

Since the rain can cause the complete loss of the signal (interfering or interfered), no interference coming from correlated and partially correlated TX stations (where interfering signal takes the same path of the interfered signal) is calculated.
From the multipath point of view the margins as per the above picture can be considered typical values; only the correlated interferences due to adjacent channels are ignored because the RX filters of the equipment are able to keep the received signal from the interfering ones.

Further explanations can be found in the Pathloss Handbook.