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Impact of Threshold Degradation on Availability of Digital Fixed Radio Links

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Abstract. With the growing density of fixed radio links, the possibility of system interferences is rapidly increasing. The most significant consequence is threshold degradation of receivers. The reuse of radio channels at the same location often causes threshold degradations that are above the recommended values.
An analysis of the impact of threshold degradation on the link availability is presented. Results prove that the impact is relatively low, provided that the link has been planned with a sufficient fade margin.

Key words: fixed radio links, system interferences, threshold degradation, fade margin, availability.

Vpliv degradacije praga sprejema na razpoložljivost digitalnih fiksnih radijskih zvez

Povzetek. Z rastočo gostoto fiksnih radijskih zvez se hitro povečuje tudi možnost sistemskih interferenc. Najbolj značilna posledica interferenc je degradacija praga sprejema sprejemnikov. Pri ponavljanju radiofrekvenčnih kanalov na isti lokaciji pogosto nastajajo degradacije praga sprejema, ki so večje od priporočenih. Analizirali smo vpliv degradacije praga sprejema na razpoložljivost zveze. Rezultati kažejo, da je ta vpliv sorazmerno majhen, če je bila zveza načrtovana z zadostno rezervo moči sprejemnega signala.

Ključne besede: fiksne radijske zveze, sistemske interference, degradacija praga sprejema, rezerva sprejemnega signala, razpoložljivost.

1 Introduction

Our agency first met the problem of threshold degradations due to system interferences in 2001. Some operators, using computer aided analysis, established that in some cases, especially with the reuse of radio channels at the same location, the threshold degradations were higher than was generally recommended by the ECC-01-05 recommendation.

Their remarks were taken into consideration in part and the reuse of radio channels was avoided in some cases, but due to the lack of an appropriate software tool, it was neither possible to verify their complaints nor to evaluate the necessity of such procedures.

Opinions of the consulted experts on the gravity of this problem and appropriate tools for national frequency planning differed widely. There were some opinions that we should use the same recommendations and tools as used in the Vienna Agreement. According to it, the maximal permissible threshold degradation caused by one transmitter is 0.2 dB (the new proposal is 1 dB). The strict use of these limitations in national frequency planning would practically prevent the reuse of radio channels at the same location, especially on lower frequencies. This would not be an economic use of the frequency spectrum.

The recommendation ECC-01-05, which covers national planning of digital radio links, generally prescribes the upper limit for threshold degradation from 0.2 to 1 dB (interference of a single transmitter) and 3 dB (aggregate interference caused by all transmitters). However, in cases of dense network deployment it allows higher threshold degradations, provided that performance and availability objectives can still be met.

We decided to research the relation between the threshold degradation and performance/availability characteristics of a link.

The paper is a technical report giving results of this research. The author, wanting to present the problems to a wider public, avoided the use of complex formulas.

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2 Setting the problem

In Fig 1 (below) we see the mechanism of interference. The interfering signal of the transmitter X is attenuated by the discrimination of both filters (X and U), loss of the path, and sum of ratios between the main and the side lobes of both antennas. The most critical case is when the transmitters X and V operate at the same location and when they use the same radio channel. In such case the interfering signal is attenuated only by the ratio between the main and the side lobes of the transmitter X antenna (besides the loss of the path).

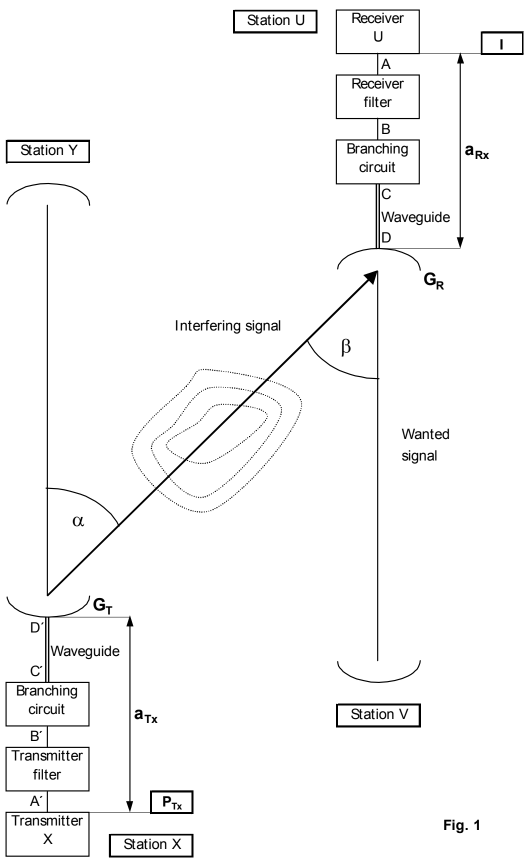

Fig1. Mechanism of the interference caused by transmitter X on receiver U

Reusing radio channels at the same location often leads to an unfavourable situation, very often causing threshold degradations that exceed the recommended maximal value 1 dB.

The belief that interference could be avoided if we provided a sufficient angle between the two links (e.g. more than 7 beam widths) has a very poor technical background. The first null of the radiation pattern occurs at the angle which is approx. one width of the main lobe apart from the peak. If we increase the angle between the links, we face the side lobes which determine the amount of interference. The size of the side lobes does not necessarily decrease with the increasing angle – with some antennas it remains the same or it even increases. One of the numerous proofs of these facts is given in the next chapter.

3 Example of threshold degradation calculation

For illustration, consider this practical example of the calculation of threshold degradation that a 100mW, 2x2 Mbit/s, QPSK modulated transmitter of the link Trstelj – Anhovo causes to the receiver of the 4x2 Mbit/s QPSK modulated link Trstelj – Kuk. The receiver threshold on the location Kuk is – 88 dBm (without degradation).

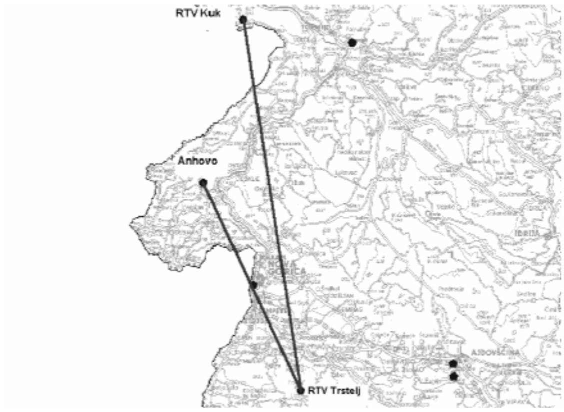

Fig.2 Path of the Trstelj – Kuk and Trstelj – Anhovo links

Since the angle between the two links was quite large (almost 17º) compared to 1º of the beam width of antennas, the initial plan was to use the same radio channel for both links (18470 MHz).

However, results of an analysis (Fig. 3) performed by the computer program PATHLOSS (produced by the company CTE Ltd.) proved a very large threshold degradation (TD = 18.23 dB) of the receiver at the location Kuk. (Fig. 3)

Case 4	Victim RX	Interfering TX
	LJ-0TX07-A	SW-01132-A
Coordinating Station	SW-01132-A	NW-01034-A
Antenna model	VHP4-180A	VHP4-180A
Discrimination Angle (°)	0.00	16.55
Frequency (MHz)	18470.00 V	18470.00 V
V-I Distance (km)	38.06	
Antenna Discrimination (dB)	40.41	
Interfering Signal (dBm)	-82.97	
Objective (dBm)	-107.00 (-24.03)	
Threshold Degradation (dB)	18.23	

Fig.3 Results of the threshold degradation analysis of the receiver

Due to concerns about the amount of threshold degradation, a different radio channel was assigned to the Trstelj – Anhovo link (18483.75 MHz with different polarization), with which a very low threshold degradation (TD = 0.1 dB) of the receiver at the location Kuk was achieved.

Later research, presented in the following chapters, proved that it was not absolutely necessary to use different radio channels for the two links.

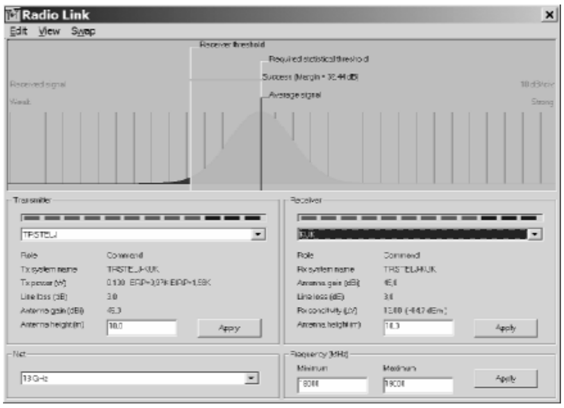

Fig. 4 Statistical distribution of the receiver input signal

4 Statistical distribution of the receiver input signal

The plan was to study the influence of relatively large threshold degradation on the availability of the link. The first task in this direction was to get the statistical distribution of the receiver input signal (without interference).

The Longley – Rice propagation model and the computer program Radio – Mobile was used to analyze the already introduced Trstelj – Kuk link. The results are given in Fig. 4.

The average input signal is about 40 dB above the receiver threshold (fade margin). The surface under the curve to the left of the receiver threshold (the dark part) compared to the total surface under the curve represents approximately the time when the input signal will be under the receiver threshold (outage time). If threshold degradation (TD) occurs, the receiver threshold line must be moved to the right for the amount of TD and the outage time will increase.

However, this means that when the link is planned with a large fade margin it can withstand large TD without any essential increasing of the outage time.

The presented curve, being very illustrative for understanding the essence of the problem, is not precise enough to get reliable numerical results.

5 Performance and availability of a link

There is a great number of phenomena that have an impact on performance and availability of a link. The two most critical phenomena are multipath fading and rain fading. At lower frequencies, the impact of multipath fading prevails.

The duration of this phenomenon may be from small fractions of a second to several hundred seconds. Analyzing the performance and availability of low frequency links requires the calculation of at least two parameters: Seriously Errored Seconds Ratio, which is the accumulation of error states lasting less than 10 consecutive seconds and unavailability which accumulates the states lasting more than 10 consecutive seconds. However, at frequencies somewhere above 10 GHz, the rain fade, which practically always lasts more than 10 consecutive seconds, prevails. If it is established that annual unavailability (total outage time) of a medium grade high frequency link is within the limits defined by the recommendation ITU-R F.696, then one may presume that performance and availability of the link are acceptable.

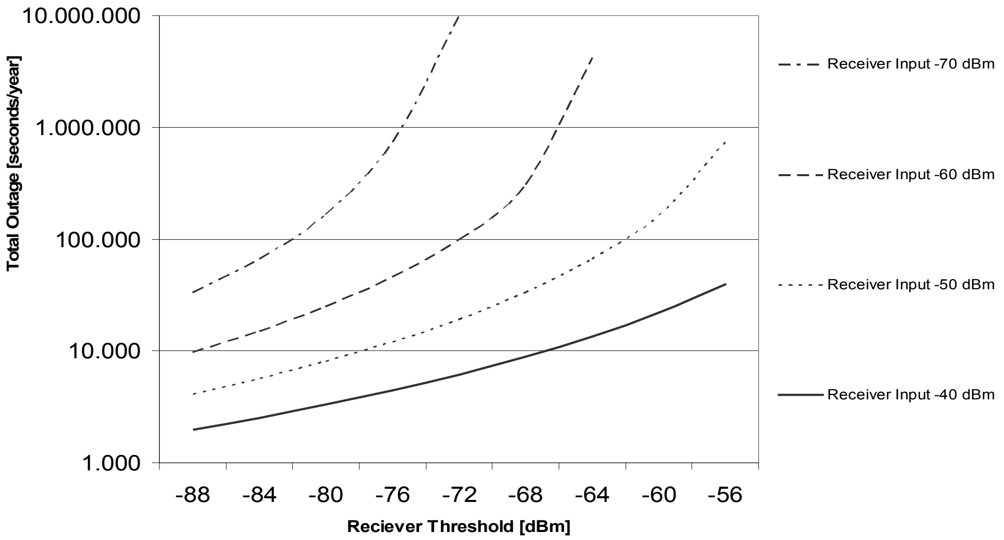

Fig. 5 Total outage time as a function of receiver threshold

6 Total outage time as a function of threshold degradation

Analysis of the introduced Trstelj – Kuk link continued with the use of the computer program PATHLOSS calculating interferences and reliability in accordance with recommendations ITU-R P.452 and ITU-R P.530. The total outage time as a function of the receiver threshold with different input levels of the receiver signal was calculated (Fig. 5).

The uninterrupted curve (receiver input -40 dBm) corresponds to actual circumstances on the Trstelj – Kuk link. The receiver threshold on the location Kuk is – 88 dBm (without degradation). The actual threshold degradation of about 18 dB (see Chapter 3) increases the total outage time, but it is still below 10,000 sec/year that is according to the recommendation ITU-R F.696 quite acceptable for the link of a medium grade. The reason for this insensitiveness is a relatively high fade margin (48 dB). Unfortunately, many project engineers still believe that a fade margin of 20 dB or even less is enough to get a reliable link. In Fig. 5 this would correspond approximately to the curve for the receiver input -70 dBm. Clearly, even without any interference there would be a total outage time about 40,000 sec/year, which is already more than it is acceptable for a link of a medium grade. However, the slightest threshold degradation would immensely increase the total outage time (logarithmic scale!).

But if the gains of both antennas were increased for 10 dB, the receiver input would be -50 dBm (fade margin 38 dB), which would be enough to obtain quite a reliable link.

Therefore, from the chart given in Fig. 5, the outage time due to certain threshold degradation can be seen immediately along with the procedure needed to compensate the impact of threshold degradation. The chart is similar for every link, but exact values depend on many parameters, such as path profile, geoclimatic factors, type of modulation, receiver threshold, etc.

An exact analytic function could probably be derived, but would certainly be highly complex and unclear. The only reasonable solution is therefore that the chart is made for every critical case separately using available software tools.

It has already been suggested to some software tool producers to include such a chart in their programs and their first responses are promising.

7 Conclusions

In planning fixed radio links, the reuse of radio channels at the same location often causes threshold degradations that are above the recommended values. Increasing the angle between the links does not assure avoidance of interference. For dense network deployment, higher threshold degradations can be accepted if performance and availability objectives can still be met. Fulfilment of this condition can be easily seen from the chart presenting the total outage time as the function of receiver threshold. The links planned with high fade margins can withstand high threshold degradations with no essential loss of availability.

8 References

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Milan Šval received his BSc and MSc degrees in Electrical Engineering from the University of Ljubljana, Slovenia, in 1969 and 1987, respectively. In 1970 he joined the company Iskra where he was engaged in the development of microwave components. From 1980 – 92 he was leading the Microwave Department of Iskra Elektrozveze.

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