Harmful Interferences to Aeronautical Radio Communications
Arising from Passive Intermodulation

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Abstract

This paper introduces a real case study related to a harmful interference problem which affected the Aeronautical Mobile Service radio communications, between the Lisbon International Airport’s Control Tower and the aircrafts approaching the runway. Passive Intermodulation (PIM) was in the origin of this problem. The paper will address this type of case study and explain its origins.

1. Introduction

The radio communication systems play a crucial role in the life of modern societies, having a direct impact on the vigorous growth of the number of RF stations and allocated frequencies.

Often, a large amount of radio sources are co-located in the same site. In such environments, where several transmitters and receivers are sharing a common place, it is usual to observe harmful interferences, due to nonlinear phenomena in local RF devices, and not because of external interfering sources. Nonlinearities contribute to degrade transmitted/received signals and to generate spectral components without any interest, which are occupying resources, improperly.

Many of these phenomena may occur in transmitters, receivers, or even in passive components, with particular relevance in sites with a strong density of radio equipments radiating high RF power.

2. Case Study

The Lisbon International Airport has reported a harmful interference which was affecting the frequency 118.1 MHz, assigned to the Control Tower. All the radio communications between the tower and aircrafts were severely interfered, apparently, due to a sound-broadcasting emission.

The aircrafts approaching the runway were particularly harmed whenever they were flying over Monsanto – the main RF site serving Lisbon – that is shared by the most important TV and Radio operators.

Under these circumstances, it was impossible to use that frequency, and for safety reasons, all the communications have been settled over the fallback channel.

2.1. Analysis

The identification of interference sources could not be an easy task. As the radio spectrum is becoming increasingly congested, the number of signals potentially interferers grows at an inexorable pace. We can assure, even without any risk of overstatement, which in relatively small geographic areas, there are thousands of RF radiation sources operating simultaneously.
With such wide variety of sources, it is desirable to characterise, as much as possible, the interfering signal. It is particularly relevant to identify the occupied bandwidth, duration of the emission (continuous, intermittent or random), time of occurrence, signal strength, information extracted from demodulation, etc.

However, in this particular case study, we know enough about the interfering signal. On the one hand, it is a permanent emission, which provides greater flexibility to localise it. On the other hand, from demodulation, we conclude that the interference, at least, has the contribution of one radio station, because we can identify, through audio analysis, the “Radio A” programming, which operates in the area at the frequency: 104.3 MHz.

Since, it is not any intentional or illegal emission operating at 118.1 MHz, not even a frequency assigned to any other licensed service, so we are in presence of a nonlinear distortion phenomenon, owning to a nonlinear system.

### 2.1.1. Intermodulation Interference

At the moment, we know one of the emissions that is contributing to the interfering intermodulation product - “Radio A” (104.3 MHz), identified by audio analysis. However, we need to identify the other emissions. But, we take some advantage in reaching them through auditive analysis of the base band modulating signal, because we are dealing with analog modulations.

For this, we will suppress the audio modulation of the “Radio A”, leaving exclusively the emitting RF carrier. Although less audible, the “Radio B” can be identified. The frequency 90.4 MHz is assigned to the latter broadcasting station. Both transmitter systems are located on the same tower, in adjacent and collinear antenna arrays.

Assuming a third order in-band intermodulation product, we obtain the following frequency:

\[
2\omega_2 - \omega_1 = 2 \times 104.3 - 90.4 = 118.2 \text{ MHz}
\] (1)

Although this frequency seems to appear slightly by the side of 118.1 MHz, some field measurements has shown that the bandwidth occupied by the interference was about 300 kHz, overlapping in fact the affected channel (118.1 MHz). Moreover, it was noticed that the interference has vanished whenever any of those emissions was turned off, confirming that this is the product responsible for the problem reported by the Airport.

### 2.1.2. Possible Intermodulation Sources

In a radio environment there are three main points where the intermodulation can potentially occur:

- Final stages of transmitters, due to nonlinearities in power amplification circuits;
- Front-ends of receivers, due to nonlinearities in mixers and RF circuits;
- Nonlinear materials and nonlinear metal contacts, such as poor or corroded contacts in coaxial cables, waveguides, connectors, couplers, fences, steel structures, towers and masts.

Whereas the interference resulting from intermodulation generated by transmitters and receivers can be minimized with adequate isolation and filtering systems, the interference arising from intermodulation due to nonlinearities present in contacts or metallic materials can not be removed or mitigated by the same techniques.

Intermodulation products generated in passive devices may therefore arise when metallic components are in contact and in the presence of an electromagnetic field. This is because the oxides on metal surfaces, which are present in the components in contact, may behave as a semiconductor junction. So, the potential across the junction “terminals”, induced by the incident electric field, produces currents in that junction, radiating interfering intermodulation products.
2.2. Temporary Mitigation

In practice, the task of locating possible PIM sources could be complex and dilatory. In a real scenario of harmful interference, such as that described here, which involves critical communications, it is not compatible with the lapse of time, possibly long that may be necessary to the location of the PIM source. But, more important than finding the nonlinearity, is to determine which are the emissions contributing to the interfering intermodulation product to act immediately on them.

In an extreme danger situation, we should shut down at least one of those transmitters, "killing" the product by this way.

Since the interfering sources location may not be immediate, that does not mean that urgent measures should not be taken to control interference. It is therefore necessary to assess if is possible to keep the interference level below a given threshold, which does not put the affected service’s integrity at risk. If there is no such risk then, under those circumstances, some measurements should be adopted to mitigate the interfering product power level. Reducing the transmitted power level of each fundamental which contributes to the intermodulation product, it is expected to reduce the interference level. If, on the contrary, even reducing the interfering signal power level there is a clear risk that the service remains affected, then the only possible solution is to turn off the emissions. Specifically in the case study we are analyzing the power reduction of the fundamentals involved in the product has proved to be effective, so, that was the measure taken.

2.3. Interfering Source Location

The interference source location is mainly based on direction finding techniques, for example, using a receiver or spectrum analyzer, and a directive antenna, typically, Yagi, log-periodic, or loop.

After that, we just have to rivet one's attention to the peak corresponding to the interfering frequency, given by the analyzer, and rotate around ourselves in order to find the direction where that peak reaches the maximum level. The interfering source will be for sure in that direction. Sometimes, we can improve the reception level of the signal to be tracked by adjusting the antenna polarization.

Then, we can circumscribe an area around the source crossing different directions obtained in other places of analysis. If we are doing this repeatedly, we should get soon to the interfering source.

Additionally, it is strongly recommended to check if the receiver (spectrum analyzer) is not saturated. A good practice to be followed is to turn off all the pre-amplifiers, and to insert a variable attenuator between the cable and the signal analyzer’s antenna input. When a given attenuation is introduced, the interfering signal will have to drop in the same proportion. If not, there are strong suspicions to think that the analyzer is saturated, and for that reason we can not conclude anything.

In practice, it has been verified that the maximum interfering signal came from the tower where both antennas systems (from “Radio A” and “Radio B”) were installed, with major levels coming from the “Radio B” array.

2.4. Problem Resolution

Several tests were preformed aiming to isolate the problem, namely, delivering RF power only to the upper half of bays belonging to the “Radio A” array, since they are the more distant from the “Radio B” array, noticed that the interference level has decreased significantly. Complementarily, feeding only the lower set of array bays, the interference was stronger. So, we were more and more convinced that was the “Radio B” antennas array the real source of the problem.

After replacing the antenna systems and multiplexing the “Radio B” in the same antenna, it has been confirmed that it was in fact the problem.
Inspecting the old bays, we concluded that was indeed passive intermodulation phenomena the source of interference. As we can see in Figure 1, the antennas exhibit an advanced degree of degradation, namely, corrosion and oxidization.

3. Conclusions

It was clear that a problem of nonlinear distortion, in particular passive intermodulation, can lead to harmful interferences with a real impact, which put at risk the integrity and safety of such critical radio service, as is the Aeronautical Mobile Service.

According to the facts explained before, it is evident that all spectrum users should have additional care and more sensitivity to problems like this, adopting a continuous plan of maintenance and the best engineering practices, in order to minimize the negative impact arising from passive intermodulation.

![Figure 1 – Bay antenna in the origin of PIM interference problem.](image)

4. References