Receiver Induced Intermodulation Interference in GSM-900

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Abstract –**In this paper a specific case related to intermodulation interference caused by co-existence of GSM-900 and UMTS-900 technologies on the same site has been investigated. The analysis and experimental results showed that the interference is not induced into the transmission path between the User Equipment (UE) and the Base Station (BS). It is a result of overloading the input stage of the UE's receiver thus driving its operating point into a nonlinear region.**

Keywords –**Co-existence Intermodulation interference, 3G, UMTS, GSM.**

I. Introduction

The market share of GSM services recently has reached its peak. In the most general case, three or more network operators share a limited frequency resource, which in many cases could cause interference problems the solving of which raises the need of taking specific measures related to planning, interference suppression or coordination. The interference problems become more severe with the implementation of broadband service (UMTS) in the frequency limited GSM-900 band. System planning takes into account co-channel and adjacent channel interference [1]. The main cause of these interference signals is the frequency reuse in the cellular network, signals falling outside the compensation range of the delay equalizer and out-of-the-network emissions of unwanted signals [2].

In some occasions, interference occurs due to non-linear performance of the transmission path [3]. For example, two or more UMTS or GSM signals radiated from co-sited or close spaced antenna systems can generate Intermodulation (IM) products of third and/or higher order that can fall within a certain frequency of the receive channel. Similar case could arise, when several GSM channels mix and generate IM products, which affect the UMTS service, operating in the upper frequency band as described in [4]. Another problem related to the generation of IM products is considered in [5], where the authors analyse several scenarios. One is the case when an impaired service UMTS base station is geographically closely located with a GSM base station and another the case when they are operating on physically separated areas. Usually IM products up to the fifth order are taken into account. Complexity arises because of the broadband character of the UMTS signal - it can generate IM products by itself. The paper discuses and evaluates some aspects of UMTS and GSM co-existence interference. The authors also propose a new frequency planning strategy, that takes into account out-of-band IM interference signals and improves QoS of the 3G wireless network [5].

In this paper the intermodulation interference caused by co-existence of GSM-900 and UMTS-900 technologies on the same site is investigated. In point II the sources of intermodulation interference are considered. In point III the results from the measurements of the induced interference as a result of overloading the input stage of the UE's receiver are presented. Finally in the conclusion a recommendation for mitigation of such interference is given.

II. Sources of Intermodulation Interference

Main cause of the Intermodulation interference is the non-linear performance of the transmission or receive path, where several signals are mixed and generate IM products. There are several models to describe this type of induced intermodulation. One of the most adequate models is described in [7]. Despite the fact it was initially created do provide compliance between aeronautical services and broadcast services, same analyses and conclusions can be delivered and applied to any type of radio networks. The ITU defines four types of interference mechanisms:

- TypeA interference – caused by unwanted emission into the operating channel band from one or more out of band transmitters.
  - Type A1 interference mechanism occurs when one on more out of band transmittersinteract and produce intermodulationcomponents into the operating channel. Transmitter side Passive Intermodulation Distortions (PIM) are a typical case of A1 type intermodulation interference.
  - Type A2 interference is occurred when spurious emissions of an out of band transmitter fall within the receive band of the service. It happens only when the transmit and receive bands are in immediate proximity.

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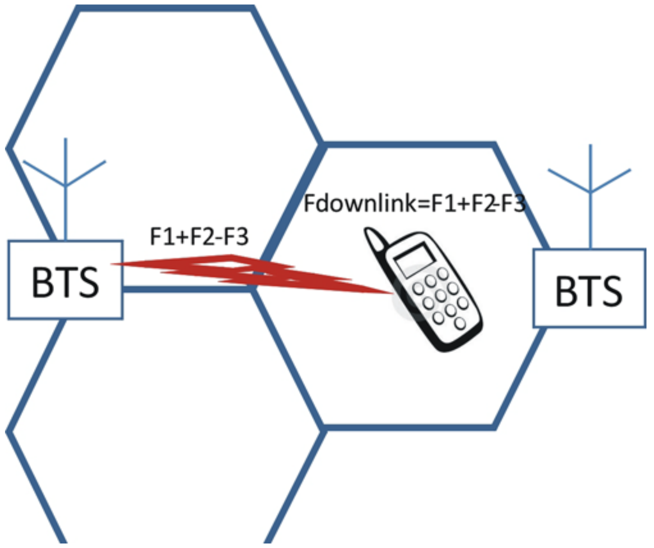

Fig. 1. Type A intermodulation interference example. A base station produces and transmits an intermodulation product with the same frequency as the downlink frequency of the neighbor BTS. The interference signal propagates in the coverage area

- Type B interference is generated in the receiver side, resulting from out of the band broadcasted signals with substantial levels (Fig. 2).This type of interference is instrument specific and can be proved with standardized receivers only. The general purpose instruments in general have wide dynamic range and may not detect B-type of interference.

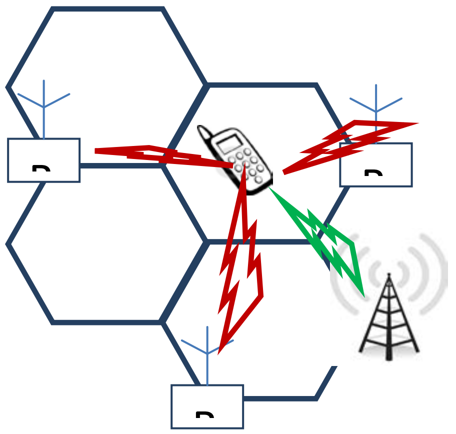

Fig. 2.Type B intermodulation interference. The interference signals are induced in the receiver side. “Trigger” station – in green, “Cut-off” Stations – in red

- B1 type of interference occurs when the UE receiver is loaded with a particularly strong signal; it drives the operating point of the receiver’s input stage to a nonlinear region of its operating characteristic. Once this happens, high order products are generated in the receiver’s circuitry. In order this type of interference to occur, it is necessary two or more broadcasted signals to have a frequency relationship, which in a non-linear interact to produce an intermodulation product within the wanted RF channel. At least one of these signals must have a level, strong enough to drive the receiver into non-linear region (Trigger level). The other signals have to have levels which are detectible (Cut-off level) in order to generate intermodulation products. Usually third and fifth order intermodulation products are considered, because their products fall whiting the receive band of the system. However, analyses should include signals from all sources that are above the Cut-off level and include even and odd order products, up to fifth order (beyond the limitations proposed by ITU [7]).
- Type B2 interference may occur when the UE receiver is overloaded by one or more signals with very high levels. It leads to desensitization in most of the cases or complete loss of receiver operation [6, 7].

III. Experimental Results

In order to correctly determine the type of interference the authors have performed research and measurementsat a location where interference problems occurred after the installation and commissioning of 3G UMTS service in the 900MHz band. In this location the UMTS service was degraded and the quality of service in the downlink was deteriorated.

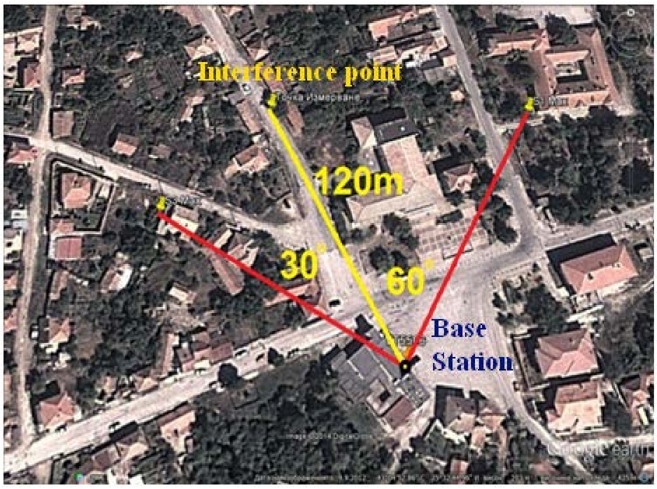

Fig. 3. Aerial photo of the problem area

After initial analysis in order to find out the reason for this service degradation and suggest possible solutions of the problem, the hypothesis was that the broadband UMTS carrier mixed up with the existing on site narrowband GSM carriers thus producing IM products that affect the GSM service.

The location of the problematic area was narrowed down to a circular shaped region of 10 m in diameter, situated 120 m NW from the base station (Fig. 3). The uphill terrain profile suggested that this region is within the antenna beam peak of the base station. The instruments used for interference detection were standard GSM terminal and AniteNemo FSR-1 standardized measurement receiver. Fig. 4illustrates the frequency spectrum in case of two operators, where one of the operator’s carriers (Broadcast Control Channel - BCCH) are completely absorbed into the noise, created by the other operator’s UMTS and GSM service carriers.

The color marking of the figure is as follow: - Orange – first operator’s channels (Dark orange – UMTS frequencies); Red – second operator’s channels; Green – channels of other mobile operators; Yellow – BCCH channels of the second operator and Grey – guard frequency bands.

However, the on-site measurements with a spectrum analyzer showed that no interfering signals are propagated in the transmission channel. This conclusion was confirmed with UMTS carrier ON and OFF, in the case where the other operator’s carrier was clearly detectable (Fig 5).

A similar picture was noticed when a service check-up was performed with a standard Sony-Ericsson handheld UE terminal. The service was interrupted and phone calls were impossible to be performed.

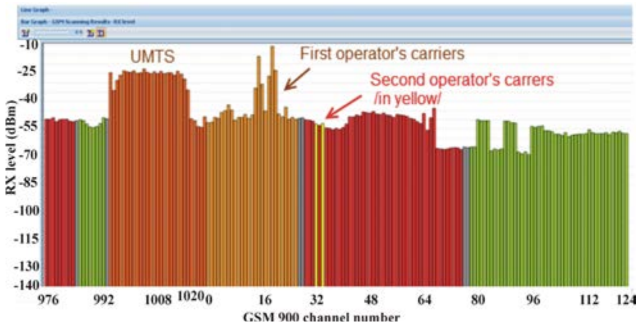

Fig. 4. Snapshot of the 900MHz spectrum in the test point, measured with standardized measurement receiver

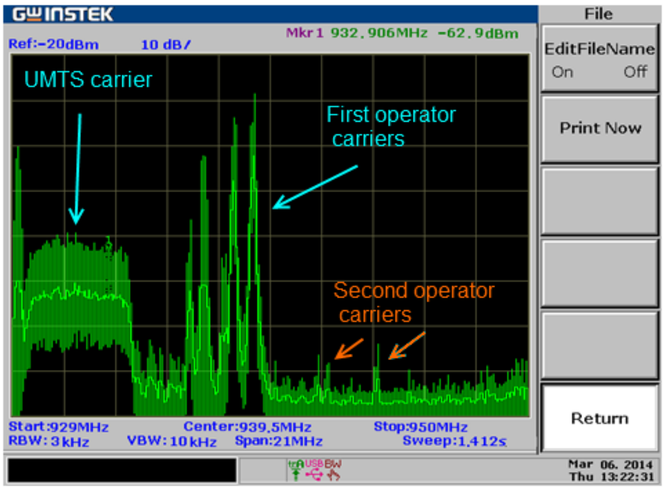

Fig. 5. Snapshot of the 900MHz spectrum in the test point, measured with spectrum analyzer

Analysing the significant difference in the resluts from Fig. 4 and Fig. 5, we came to the conclusion that the interference is of the type “B2”, i.e. it is not generated in the tranmission path and induced into the user receiver equipment. Due to the relatively high level of the first operator’s carriers (and proximity to the base station), the interference in such a standartized UE terminal is generated because of the nonlinear input charecteristics of its receiver. This conclusion was confirmed from the results of the measurements obtained when introducing a 10 dB attenuation pad to the input of the receiver as shown in Fig.6.

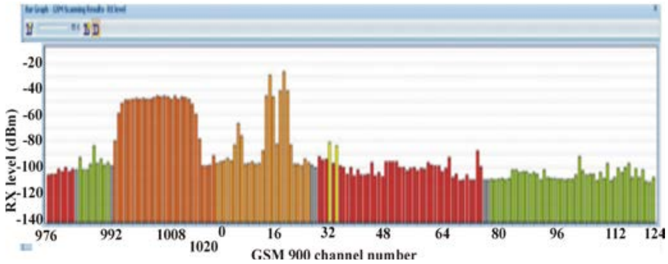

Fig. 6. Snapshot of the 900MHz spectrum in the test point, measured with standardized measurement receiver, with 10dB attenuation pad

After adding the 10dB pad, the interference (noise) levels dropped by more than 30dB and second operator’s carriers became clearly noticable. For an additional confirmation of this conclusion different measurements were conducted by decreasing the carrier transmission levels form the base station. With every drop of the carriers a decrease in the ‘B2’-type interference product was observed until it dissapeared completely after a total of 20 dB decrease of all carriers.

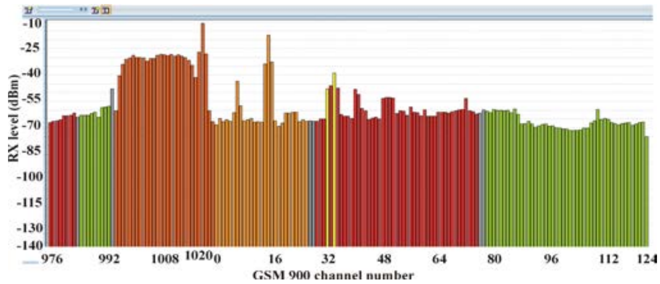

Fig. 7. Snapshot of the 900MHz spectrum in the test point, with a new set of GSM frequencies of the First operator

Several attempts to mitigate the interference were taken by rearrangement of the frequency allocation on behalf of the first operator. The new frequency set was choosen in the way that the discrete value intermodulation products (of the GSM carriers) not to coincide with the BCCH carriers of the Second operator (Fig. 7).Some improvements of the signal-to noise ratio could be noticed on the measurement receiver and improvement of the quality of service of the Second operator on the UE handheld terminal, however these attempts didn’t lead to complete erradication of the problem and in case of pracitcal implementation it will lead to limitations and bring additional complexity from the frequency allocation point of view.

IV. Conclusion

In this paper, a special case of type “B” intermodulation interference caused by co-existence of GSM-900 and UMTS-900 technologies on the same site was considered. Despite the fact that in the literature interference mechanisms are well explored for other types of radio communication equipments, authors had not found similar analyses related to the operation of UMTS and GSM base stations in vicinity to one another. Such type of interference can raise serious operation problems and should be taken into account especially in the case of heterogeneous wireless networks (where different types of micro, pico and nanocells coexist) and with the introduction of 4 and 5G technologies. There is no straight-forward solution of the problem, however with a careful selection of transmit powers and operating frequencies on behalf of the mobile operators having base stations in vicinity of one another the problem can be successfully mitigated.

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