Continuous GSM interference from intermodulation

IDA 2 can determine the causes

The antennas in most modern cell phone stations are usually very close together: GSM 900, GSM 1800, UMTS and LTE, each with separate antennas for uplink (RX) and downlink (TX) and for covering various sectors. It is therefore no wonder that they affect each other. The so-called “rusty bolt effect”, rectification caused by corroded metal fastenings – which are found everywhere on roofing sheets, guttering, lightning conductors and even the antennas themselves – is enough to generate intermodulation. The intermodulation generally originates from the TX antennas, with their comparatively high field strengths, and interferes with the RX channels. Such intermodulation is typically only measurable in direct proximity to the RX antennas, so it is impossible to take a bearing on it from in front of the building. If the field strengths are too high to measure the intermodulation because of the closeness to the TX antennas, the analyzer can be connected directly to the RX antenna base, i.e. at the receiver input itself.

This particular case concerns a continuous impairment in the GSM 900 band occurring in uplink channel 33 = 896.6 MHz and in other channels. The interference affected only one sector but various numbers of timeslots. Other GSM signals were thus the most likely cause, making it worthwhile to investigate possible interference mechanisms.

2nd order intermodulation products (IM2) of two signals with frequencies f_1 and f_2 occur at

$$f_{IM2} = f_1 - f_2 \qquad \text{and} \qquad f_{IM2} = f_2 - f_1$$

3rd order intermodulation products (IM3) are generated as follows:

$$f_{IM3} = 2f_1 - f_2 \qquad \text{and} \qquad f_{IM3} = 2f_2 - f_1$$

The IM3 products from interaction of GSM 900 downlink channels 1 to 124 (935.2 – 959.8 MHz) occur in the frequency range 910.6 to 984.4 MHz, so they cannot be the cause of the interference in channel 33 = 896.6 MHz. In contrast, the many IM2 products formed by the simple difference between the channel frequencies for GSM 1800 and GSM 900 are possible culprits, so we will focus on the IM2 products in this investigation, which is based on a real situation. Measurements were made 175 m away from a GSM 900/1800 base station at about 60° to the main lobe direction.

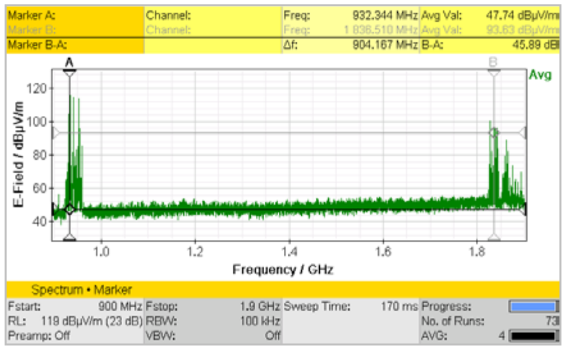

Figure 1: Overview of the GSM 900 and GSM 1800 frequency range. The differences between the many frequencies shown in the spectrum could fall within the GSM 900 uplink range. Example (markers A and B): 1836 MHz downlink – 932 MHz downlink = 904 MHz uplink. The field strengths of over 100 dBµV/m are also enough to produce intermodulation in non-linear structures.

Practical procedure

Step 1

First of all, we need to find out if the interference can be measured in the vicinity of or directly on the RX antenna of the impaired channel. In this particular case, the continuous impairment could be measured and showed a GSM signal structure similar to that of a control channel (BCCH), but could no longer be detected at a slightly greater distance. The cause could not therefore be determined directly.

Step 2

Next, it is best to search for the strong transmitting channels in the GSM 900 and GSM 1800 bands. The IDA 2 Multi-Channel Power measurement mode with display of RMS and maximum (MAX) values is ideal for this. It provides a quick and precise overview of hundreds of channels. The results are also available as a list, which can be exported.

Figure 2 shows channels in the GSM 1800 band. The channel with index number 176 (green arrow), for example, has a high, virtually constant level, which makes it easily identifiable as a control channel (BCCH). The BCCHs can be suspected in each case as being the source of any continuous impairment. The list view shown in figure 3, arranged in order of maximum field strengths, shows this channel in fifth place. A total of six channels cause field strengths in excess of 100 dBµV/m.

A further measurement is made in the GSM 900 band to determine the strongest channels there. The result is shown in figure 4: Nine transmitting channels with field strengths above 100 dBµV/m.

Step 3

The next question is: Can the six and nine downlink channels thus determined produce 2nd order intermodulation products that would interfere with uplink channel 33?

It is a good idea to produce an EXCEL table of the difference frequencies for the 54 possible combinations. The channel numbers (ARFCN, absolute radio frequency channel numbers) and the associated frequencies in MHz are entered rather than the IDA 2 internal index numbers.

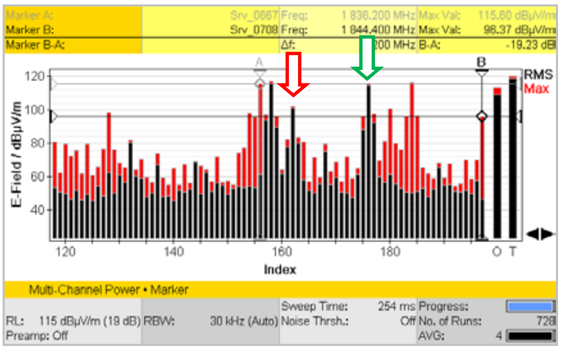

Figure 2: Multi-Channel Power measurement in the GSM 1800 downlink band, bar graph view. Control and traffic channels (BCCH and TCH) are clearly distinguishable by the difference between the RMS and MAX values.

Table View: Detailed

Index	Channel	Fmin	Fmax	Max
198	Srv_0709	1 844.525 000 MHz	1 844.675 000 MHz	116.99 dBµV/m
158	Srv_0669	1 836.525 000 MHz	1 836.675 000 MHz	116.93 dBµV/m
156	Srv_0667	1 836.125 000 MHz	1 836.275 000 MHz	116.84 dBµV/m
184	Srv_0695	1 841.725 000 MHz	1 841.875 000 MHz	116.22 dBµV/m
176	Srv_0687	1 840.125 000 MHz	1 840.275 000 MHz	116.18 dBµV/m
162	Srv_0673	1 837.325 000 MHz	1 837.475 000 MHz	103.33 dBµV/m
115	Srv_0626	1 827.925 000 MHz	1 828.075 000 MHz	99.65 dBµV/m
199	Srv_0710	1 844.725 000 MHz	1 844.875 000 MHz	99.00 dBµV/m
155	Srv_0666	1 835.925 000 MHz	1 836.075 000 MHz	98.27 dBµV/m
159	Srv_0670	1 836.725 000 MHz	1 836.875 000 MHz	97.97 dBµV/m
157	Srv_0668	1 836.325 000 MHz	1 836.475 000 MHz	97.94 dBµV/m
	Others			113.94 dBµV/m
	Total			120.20 dBµV/m

Index: 4.1 • MAN • Date: 14-02-08 10:58:29

RL: 115 dBµV/m (19 dB) RBW: 30 kHz (Auto) Sweep Time: 212 ms Noise Thrsh.: Off RECALL No. of Runs: 51 Preamp: Off AVG: 4

Figure 3: List overview arranged in order of maximum levels. The bar graph and list differ due to the difference in recording times.

Table View: Detailed

Index	Channel	Fmin	Fmax	Max
87	Srv_0087	952.350 000 MHz	952.450 000 MHz	114.48 dBµV/m
31	Srv_0031	941.150 000 MHz	941.250 000 MHz	111.69 dBµV/m
29	Srv_0029	940.750 000 MHz	940.850 000 MHz	111.57 dBµV/m
10	Srv_0010	936.950 000 MHz	937.050 000 MHz	104.12 dBµV/m
117	Srv_0117	958.350 000 MHz	958.450 000 MHz	103.79 dBµV/m
121	Srv_0121	959.150 000 MHz	959.250 000 MHz	103.24 dBµV/m
63	Srv_0063	947.550 000 MHz	947.650 000 MHz	102.79 dBµV/m
55	Srv_0055	945.950 000 MHz	946.050 000 MHz	102.50 dBµV/m
78	Srv_0078	950.550 000 MHz	950.650 000 MHz	102.49 dBµV/m
89	Srv_0089	952.750 000 MHz	952.850 000 MHz	99.84 dBµV/m
34	Srv_0034	941.750 000 MHz	941.850 000 MHz	99.41 dBµV/m
	Others			114.02 dBµV/m
	Total			117.48 dBµV/m

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RL: 115 dBµV/m (19 dB) RBW: 20 kHz (Auto) Sweep Time: 124 ms Noise Thrsh.: Off RECALL No. of Runs: 1 142 Preamp: Off AVG: 4

Figure 4: Multi-Channel Power measurement in the GSM 900 downlink band, list overview.

ARFCN	Down 1800	709	669	667	695	687	673
Down 900		1844.6	1836.6	1836.2	1841.8	1840.2	1837.4
1	935.2	**909.4**	**901.4**	**901.0**	**906.6**	**905.0**	**902.2**
29	940.8	**903.8**	**895.8**	**895.4**	**901.0**	**899.4**	**896.6**
31	941.2	**903.4**	**895.4**	**895.0**	**900.6**	**899.0**	**896.2**
55	946.0	**898.6**	**890.6**	**890.2**	**895.8**	**894.2**	**891.4**
63	947.6	**897.0**	889.0	888.6	**894.2**	**892.6**	889.8
78	950.6	**894.0**	886.0	885.6	**891.2**	889.6	886.8
87	952.4	**892.2**	884.2	883.8	889.4	887.8	885.0
117	958.4	886.2	878.2	877.8	883.4	881.8	879.0
121	959.2	885.4	877.4	877.0	882.6	881.0	878.2

Table of the frequency conversion products of GSM 1800 and GSM 900 downlink frequencies. The frequencies that lie within the GSM 900 uplink band are shown in bold type.

The table shows the resulting difference frequencies. The frequencies that correspond to a GSM uplink channel are shown in bold type. It is evident that the impairment in uplink channel 33 = 896.6 MHz (shown in red) can only be generated from the downlink channels 29 = 940.8 MHz and 673 = 1837.4 MHz, i.e. not from the very strong channel 687 at 1840.2 MHz. The channels that could be the cause of the impairment in channel 33 are shown by the red arrows in figures 2, 3 and 4.

Step 4

This still preliminary result now needs to be checked regarding its frequency and time characteristics.

The spectrogram depicted in figure 5 shows some continuous signals in the GSM 900 uplink band that are of approximately equal strength, which are normally not present in the uplink direction (blue / red arrows). The frequencies match the intermodulation table. The typical horizontal bars of uncontrolled frequency conversion are also visible (black arrows). These frequency conversion products only occur, of course, when both the TX channels causing them are "on air".

The time domain measurement shown in figure 6 confirms the GSM structure. The duration and repetition of the timeslots is within the GSM standard: In each case, seven timeslots are occupied by telephony (GMSK modulation, constant level), and the eighth timeslot is used for EDGE (8PSK modulation, variable level). Typical for a BCCH: All timeslots are continuously occupied and have the same maximum level. A BCCH in the GSM downlink is thus proven to be the source of interference.

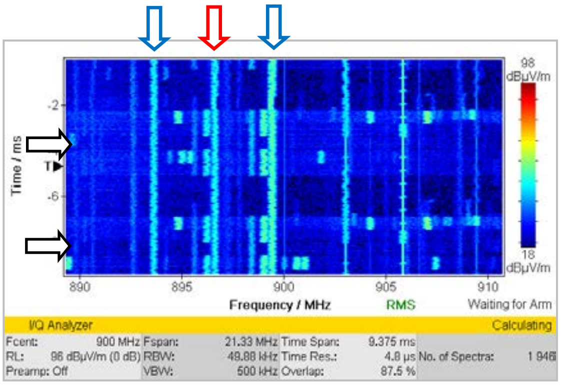

Figure 5: Spectrogram. Section of the GSM 900 uplink band. The strong constant signals are atypical for the uplink direction.

Figure 6: The time characteristic of the signal at 896.6 MHz shows the typical structure of a GSM downlink BCCH with its timeslots. All slots are occupied; one is filled with a dithering EDGE signal.

Causes and remedies

- First check that the interference is not due to remote co-channel use.
- If intermodulation due to the rusty bolt effect is thought to be the cause, cleaning the corrosion from the metal parts will not bring about a long-term solution, as new corrosion will form rapidly.
- In this case, the affected antennas are found in the direct vicinity.
- As proof, starting with your own TX channels if necessary, the possible causes should be switched off one at a time briefly (1 second is enough) and the neighboring RX channels observed.

Once the intermodulation mechanism has been established, the following are possible remedies:

- Change the channel for TX1 or TX2 or RX.
- Reducing the TX field strengths incident on the RX antennas can result in great improvements.
- Changing the sectors at the TX location can effect great improvement due to the non-linearity of the intermodulations (and produce the opposite effect elsewhere).
- Changing the sector at the RX location is seldom useful, as rusty bolt effects extend over the entire roof area.

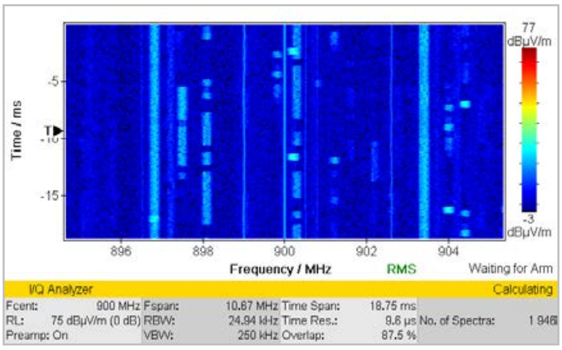

Figure 7: Example of a spectrogram with (artificially generated) intermodulation.

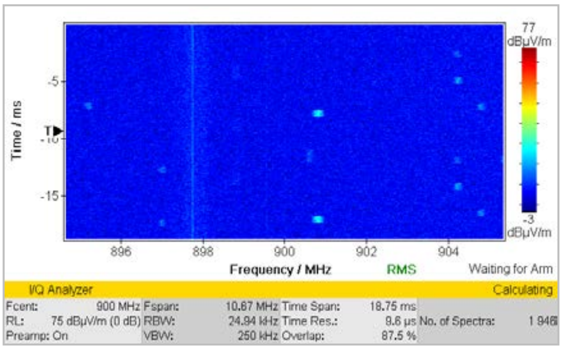

Figure 8: As above but without intermodulation.

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