MICROWAVE OVEN INTERFERENCE IN ISM-BAND LINKS

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ABSTRACT

Microwave ovens may be a problem for urban ISM-links if a line-of-sight (LOS) connection is established e.g. to a sidelobe of the receiving link antenna. A link is particularly vulnerable when it is used in cellular voice networks in which corrections in the form of a retransmission of data – suitable for packet systems carrying data only - would cause unacceptable delays. Typical recorded bit error rate values under interference were as low as 10^{-4} but a loss of synchronization is still the most severe defect. In current ISM links retransmission or bit error corrections would also reduce the user data rate. Observed effects include a loss of timing and overloading of receivers during the oven's heating cycle. In a real link, the measured relative power levels caused even by distant ovens were some 5 dB above the wanted signal. Even changing the channel does not guarantee transmission due to the limited link bandwidth. The effects of interfering emissions can be reduced by highly directional antennas.

INTRODUCTION

Fast and flexible mobile phone network installation calls for cheap and easy wireless access systems. Once the cellular base station (BTS) is installed a fixed ISM (Industrial, Scientific and Medical) band radio link (unlicensed and operating at 2.4 GHz) can be set up within a half a day to connect the BTS to the mobile access network. There is no need for digging up the road or surveying for the availability of existing lines. This explains why more than half of the current base stations use microwave links and how, in the second-generation mobile networks, the 'last mile' connection is provided by small capacity base stations which only require n*64 kbit/s as indicated in [1] and [2]. The 2048 kbit/s spread spectrum ISM link has country-specific restrictions concerning the maximum radiated power. Small-capacity and short-range links have to be cheap but provide high quality to compete with an operator's wireline installation. The goal of this study was to investigate the bit error performance in a real radio frequency environment and with currently existing commercial ISM link hardware.

SIGNALS IN THE ISM BAND

The 2.4 GHz ISM band is quite heavily used: RLAN (Radio Local Area Network) devices, Bluetooth equipment and e.g. microwave ovens operate there. A microwave oven radiates - despite the heavy screening - a continuous wave (CW)-like interference that sweeps over tens of megahertz [3] and may cause some performance loss. RLANs are also possibly harmful but when using direct-sequence spread-spectrum schemes and different channels both communication systems should work. Anyhow, a co-located outdoor version of RLAN will increase the possibility of severe interference. Bluetooth indoor devices (range 10 m) use frequency hopping and will not seriously interfere with the ISM link. Remote control door openers, diathermy instruments, industrial heaters, radars and scientific research systems might hamper the proper operation of the ISM link, too. Taking into account the number of devices sold, the power levels involved and the practically unrestricted installation practices and locations, microwave ovens in household use have real interfering potential.

THE LINK CHARACTERISTICS

The available carrier frequencies are 2416 MHz, 2429 MHz, 2442 MHz, 2455 MHz and 2468 MHz, three of which can be operated simultaneously. In Europe ETSI has specified an EIRP of 20 dBm, which limits the practical maximum antenna gain to 20 dB. The antennas used in the measurements had a 3 dB beamwidth of 25° to 30° [4], their side lobe levels were measured to be -10 to -20 dB and the respective gain values were near 15 dBi. The spread-spectrum sidebands at 13 MHz from the carrier frequency are about –30 dBc. The total bit rate in the half-duplex time division multiplexing radio interface is 11 Mbit/s and the frame length 263 μs in which the preamble and header parts use Differential Binary Phase Shift Keying (DBPSK) and a bit rate equal to 1/11 of that of the Quadrature M-ary Bi-Orthogonal Keying (QMBOK). These features provide adequate multipath characteristics [5] and communication privacy. The link has the ability to monitor the received signal level, transmitter power and performance counters such as ES, SES and UAT (Unavailability Time) for which a maximum of 17 erroneous seconds (ES) per day and one severely erroneous second (SES) per day can be accepted [6].

TEST ARRANGEMENTS

The total measurement area covered about 2 square kilometers of dense urban characteristics. Antennas were attached to the masts on the roof of buildings SM6 (3 floors), SK5 (5 floors) and VT2 (2 floors). The distance between SK5 and SM6 is 460 meters and between SK5 and VT2 400 meters. Pseudo-random bit sequences (length 2^{15}-1 = 2047 bits) from a Wandel&Golterman advanced network tester ANT-20 and Hewlett Packard HP37717C were used to measure the bit error rate (BER) in an unframed mode. A spectrum analyzer was used to check the transmitted signal and later to verify possible interference sources. The links were operated in transparent mode without frame synchronization or cyclic redundancy checks for the incoming E1 data as indicated in Fig. 1. ITU-T recommendation G.826 suggests a performance test period of one month [7] but this time only a few days' measurements were necessary to reveal the truth.

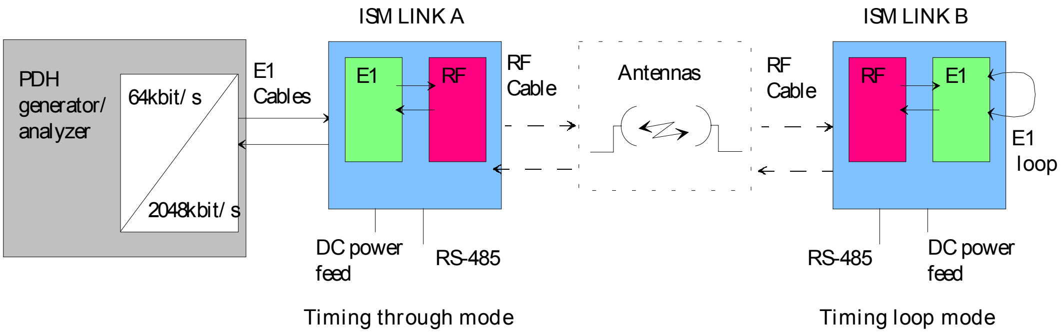

Fig. 1. Bit error measurement setup. A PDH generator/analyzer is connected to link A and link B is looped with an E1 cable. The DC power supply is 48 V. The link was configured from a terminal running in a PC via a RS-485 connection.

SOME RESULTS

Synchronization is the most critical point in radio link systems because the first link takes the clock from the incoming E1 data and the second extracts it from the radio interface. If severe Alarm Indication Signals (AISs) and high bit error counts are encountered, the second link loses its clock, and the connection is lost, see Fig. 2. In our case tests indicated very soon that the highest performance degradations occur mainly around noon on weekdays where PAT events with concurrent high BER values indicate external interference as shown in Fig. 3. The total BER was 1.6E-04. It turned out that most of the problems were caused by a microwave oven.

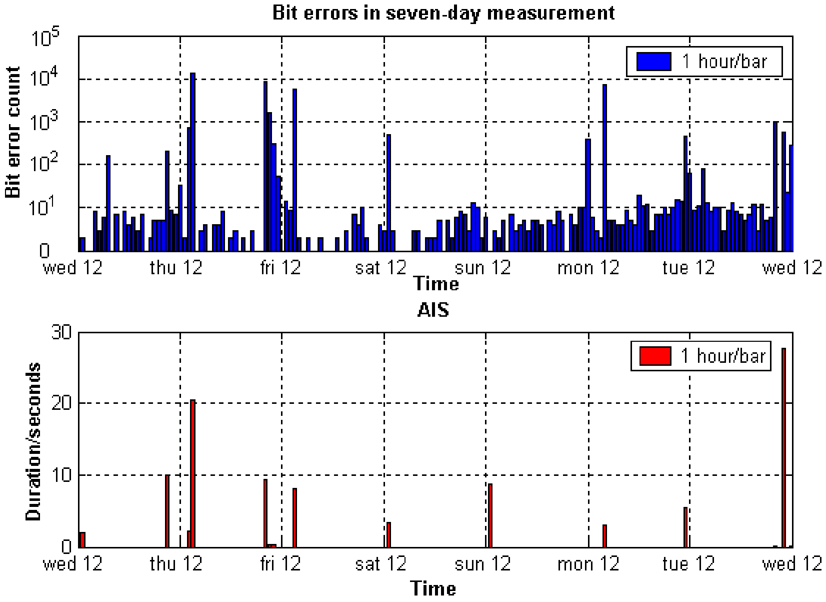

Fig. 2. A seven-day measurement between SM6 and SK5. Measurement time: from Wednesday 17th January, 12:00 to Wednesday 24th January, 12:00. Channel 5 was used with an EIRP of 20 dB. Yagi antennas were selected.

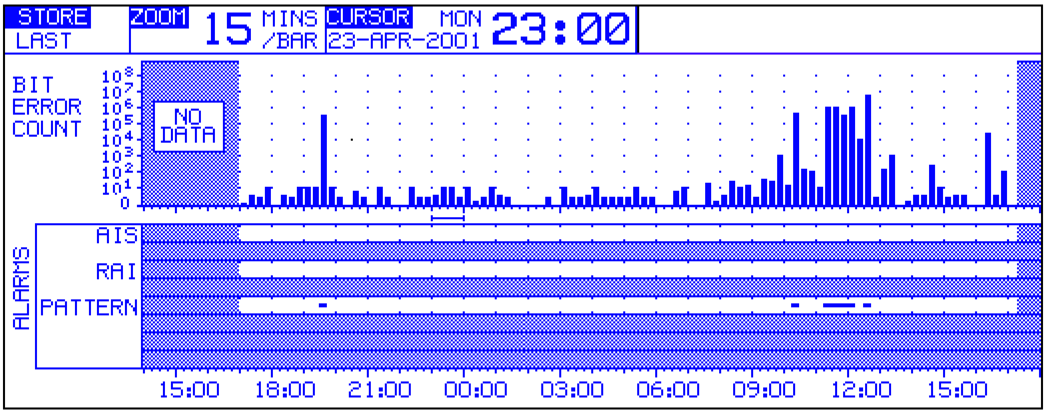

Fig. 3. 24-hour measurement results from the PDH analyzer show severe errors. The total BER is 1.6E-04.

Some confirming spectrum measurements were made at building SM6. A 1000 W microwave oven having a mug with 200 ml of water inside was located on the top floor near the window in SK5. Spectra were collected by using the peak hold function. Typically the oven's center frequency was between 2450-2460 MHz. The measurements showed that the emitted power was narrowband and was swept over some tens of MHz. In the next measurement the ISM link was located at SM6 and at SK5. The link was looped at SK5. Bit errors were measured at SM6. After a few minutes of clear transmission the oven was turned on. The system immediately failed completely. The link at SM6 generated AISs as it lost timing. The received power level at the link site - caused by the oven leakage - was found to be about 5 dB above that of the wanted signal despite the oven was not in the main beam of the antenna, see Fig. 4. The average RX power level in this experiment was - 70 dBm. In addition to this we found that the sweeping action of the oven's magnetron covered the entire allowed ISM-link bandwidth whereby we concluded that a frequency change could not solve the problem. Unknown disturbing signals, an example of which is in Fig. 5, were observed, too. It seems that only a considerable reduction of the3 dB beamwidth in conjunction with somewhat lower sidelobe levels can reduce the effects of such interfering transmissions down to an acceptable level.

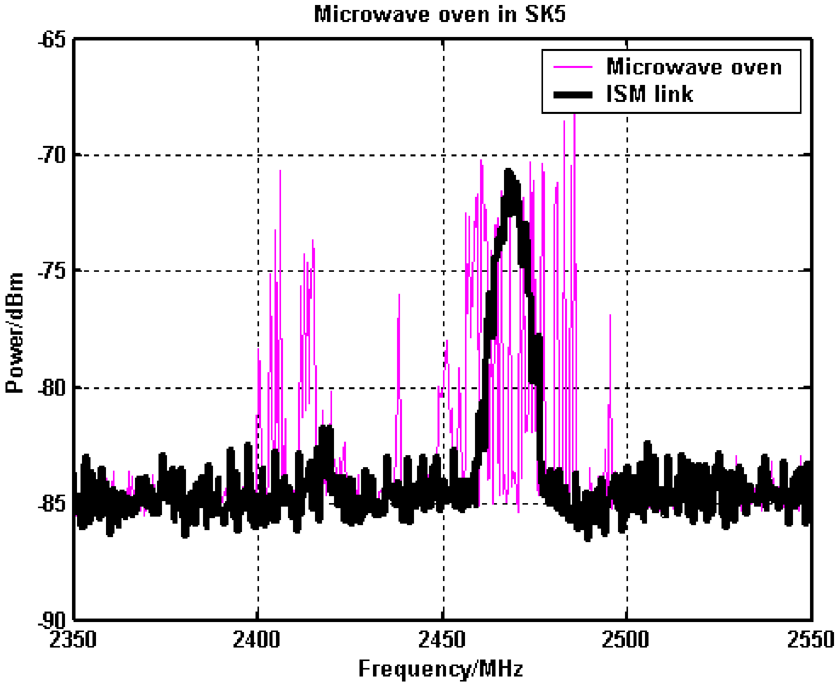

Fig. 4. The spectrum of a microwave oven versus the ISM link spectrum. This result was measured at SK5 with a yagi antenna using the max hold function. The distance between oven/ISM link and spectrum analyzer is about 460 m

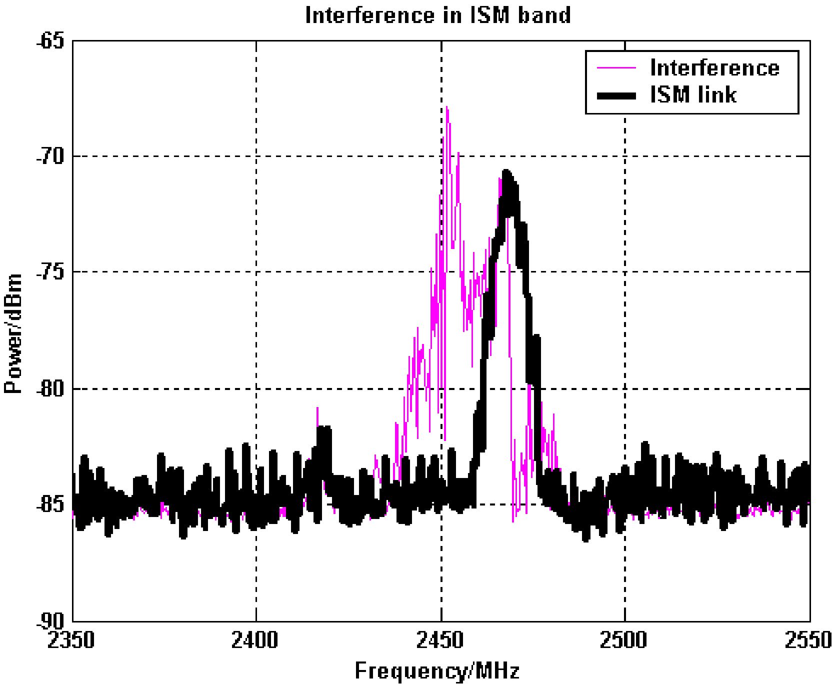

Fig. 5. The spectrum of an unknown interference source versus the ISM link spectrum. This result was measured at SK5 with a yagi antenna using the max hold function. The distance between ISM link and spectrum analyzer was about 460 m.

REFERENCES

[1] M. Clark, "*Wireless Access networks: Fixed Wireless Access and WLL Networks – Design and Operation*", Chichester, John Wiley & Sons, 2000

[2] J.Henriksson, *"Digital radio links - hops design for small capacity systems",* Lecture at Helsinki University of Technology in Espoo on 15.11.2000

[3] A.Kamerman and N.Erkocevic, "Microwave Oven Interference on Wireless LANs Operating in the 2.4 GHz ISM Band", in *Proc. Personal, Indoor and Mobile Radio Communications, The 8th IEEE International Symposium*, Chattanooga, USA, 1997, pp. 1221-122

[4] A.Räisänen and A.Lehto, *"Radiotekniikka"*, 7th edition, Otatieto, Espoo 1996

[5] I. Lindell, *"Radioaaltojen eteneminen"*, 4th edition, Otatieto, Espoo 1996

[6] F. Coenning, *"Understanding ITU-T Error Performance Recommendations",* Wandel & Goltermann GmbH, Eningen 1999

[7] Anon, *"Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate",* ITU-T Recommendation G.826, ITU February 1999