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Potential Changes to Electromagnetic Environment - Industrial Microwave Ovens

(copy 1 of 1)

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1 INDUSTRIAL MICROWAVE OVENS

1.1 About this document

This report is one of a series of four documenting the investigation and analysis of potential changes to the electromagnetic environment wrought by changes to various EMC standards that were proposed by Radiocommunications Agency-funded research. This report is concerned with the effects that industrial microwave ovens have on the electromagnetic environment near Global System for Mobile communication (GSM)-900 base-stations. It is intended that the data presented in the report will be used by Quotient Associates Ltd to enable an economic analysis of EMC studies. Consequently no conclusions or recommendations are given in this report.

1.2 Introduction

In the UK, industrial microwave ovens are allocated an ISM (Industrial Scientific and Medical) frequency band that allows them to emit radiation at high levels in the same band as GSM mobile phone handsets. Consequently, when mobile phone base stations are located in the vicinity of an industrial microwave oven their coverage over the ISM band is severely disrupted. No special ISM provision exists in the rest of Europe, therefore the European emission limit is much below that in the UK. There were concerns among UK mobile phone operators that their licensed spectrum can be legally interfered with at significant power levels. Therefore the UK Radiocommunications Agency commissioned a series of research projects [1, 2, 3] to investigate the problem.

1.3 Scenario Description

Objective: to generate data showing how an industrial microwave oven can affect the coverage of a mobile phone base station.

Variables:

- The level of emission before and after research.
- The base-station – oven separation distance.

Output: the maximum mobile phone receiver distance as a function of base-station – oven separation.

2 SPECIFICATION OF MODELLING

2.1 Victim Service

Table 1 presents key technical parameters for the telecommunications service under consideration.

Service	Frequency range	Channel bandwidth
Mobile (GSM-900)	880-915 MHz (base station receive) 925-960 MHz (base station transmit)	200 kHz

Table 1 - Parameters of the telecommunications service under consideration.

2.2 EMI Source

Industrial microwave ovens are primarily used in food production, though uses such as vulcanising rubber are also on record. For process purposes the ovens are normally conveyor fed. Consequently, depending on the size of the product being treated, a large aperture exists at each end of the oven. The levels of microwave energy escaping through the apertures are attenuated by a structure known as a choke tunnel. The research [1, 2, 3] identified that one of the primary sources of emission from an industrial microwave oven is the choke tunnel. A later stage of the research focused on improving choke tunnel design, the object being to investigate the feasibility of reducing or removing altogether the UK ISM provision. It was found that superior choke tunnel performance could be achieved using a ferrite tile lining, this was proved by fitting a practical implementation of the design to a known problem oven. The oven emissions were significantly reduced, in line with predictions. The research proved the case that the UK ISM limit could be greatly reduced.

It was found that further improvements in choke tunnel performance, on their own, would not bring total emissions below the European limit of 40 dBμV/m. The figure of 60 dBμV/m, as a new UK limit for newly installed machines, was therefore supported by the research. Measurements on an older oven demonstrated that achieving the 60 dBμV/m limit by only retrofitting improved chokes to all older ovens was not feasible.

2.2.1 Cost of implementation

The cost of implementing the improved choke tunnel on a new oven would probably be lower than the cost of a conventional choke. The cost of retrofitting an improved choke on an existing conveyor fed oven varies, depending on complexity. As a rough guide the cost of prototyping, manufacturing and fitting the chokes to the known problem oven was approximately £30,000. Generally speaking, newer ovens (eg the known problem oven) are simpler and cheaper to retrofit and older ovens are both more difficult to retrofit and suffer from poorer shielding. On older ovens simply fitting improved chokes may not provide a solution as leakage elsewhere on the oven may be significant. One older oven investigated had excessive leakage from the microwave generators. To reduce emissions the generators as well as the choke tunnels would have had to be replaced. The cost of replacing the generators was estimated to be £140,000.

2.2.2 Bandwidth of source

The bandwidth of the oven emissions varies depending on the load of the oven and on the particular oven under measurement – research by Last [4] found the bandwidth of 13 ovens (measured at the -20 dB level) varied between 0.1 MHz and 9 MHz, with a mean value of 2.29 MHz. However, the magnetron (the microwave frequency generating source) is not very stable and drifts over a day's operation. At the time of research this was affecting the mobile operator's allocation of channels 24 to 60 – over a bandwidth of around 7 MHz.

2.2.3 Emission level and signal propagation

Table 2 presents emission limits from CISPR 11 (EN 55011) and measured values from the RA-funded research.

Key Value	Level in dBμV/m measured at 30m from building wall
UK only ISM limit (886-906 MHz)	120
European limit – no ISM provision (886-906 MHz)	40
Emission level measured from problem oven prior to fitting improved chokes	79
Largest emission level after fitting of improved chokes	55
Proposed new UK ISM limit (886-906 MHz)	60

Table 2 - Key emission levels from standards and research [1, 3].

The values of propagation loss between oven and base-station calculated from sets of emission-level/distance measurements by Last [4] vary between 16.7 dB/decade and 48.5 dB/decade – the median propagation loss of 30 dB/decade will be used in this analysis.

The value of the propagation loss between base-station and mobile arising from the modified Hata model used in the research [1] is 35 dB/decade, which is appropriate for the suburban environments within which the majority of industrial microwave ovens are located. The immediate surroundings of the antennas are most important in determining the path loss and the environs of a factory building (e.g. car park, loading bay) may easily offer lower attenuation than the general surroundings of a mobile phone user.

The noise field strength at 30m from the oven building is extrapolated using the given propagation loss to a field strength at the base station. This is converted to a received noise power using the equation reported by Kenington and Bennett [5]:

$$P_{rx}(dBm) = E_b - 20\log_{10}(f) - 77.2$$

where P_{rx} is the received power at the base station, E_b is the field strength in dBμV/m and f is the frequency in MHz. In this analysis calculations are performed in the middle of the ISM band, at 896 MHz. This assumes an isotropic antenna, thus the antenna gain and any cable losses must be taken into account.

The noise due to the oven is then linearly added to the noise floor (including expected co-channel interference within the mobile network) of the base station equipment; any wanted signal must be stronger than the (*noise floor* + *oven noise*) by the required signal/noise ratio. Therefore, noise from an oven will cause a reduction in the range of the cell. The objective of the research was to limit this degradation to an acceptable degree.

The analysis is based on a simple isotropic coverage model, emissions from the oven are assumed to be isotropically radiated due to scatter from surrounding machinery. Transmissions to and from the base-station are not angularly resolved – while a base-station may have multiple, directional antennas, the analysis does not rely on this. In such a case, it may be assumed that only the antenna facing the oven will be unable to reject its noise and thus be subject to the degradation in service presented in the results below.

Figure 1 presents a schematic of the scenario with the relevant distances labelled.

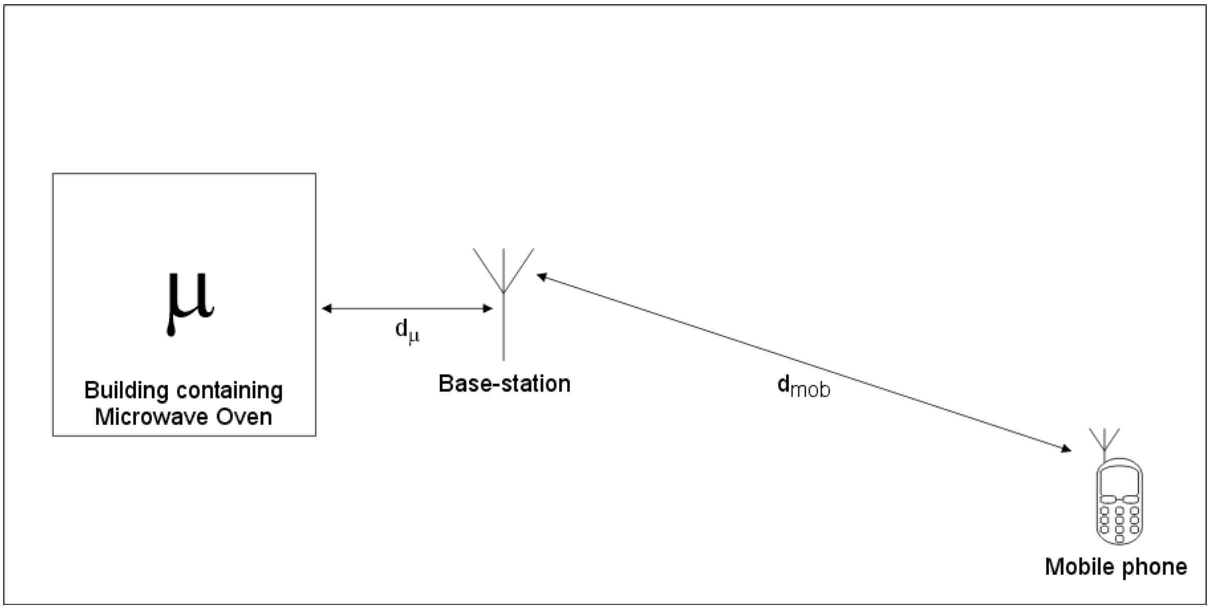

Figure 1 - The scenario presents an oven μ interfering with a base-station d_μ distant such that a mobile phone cannot transmit to it beyond a maximum distance d_{mob}.

3 RESULTS

The following tables present data calculated for three ovens. The emission levels chosen for the first two ovens (79 and 55 dBμV/m respectively) are representative of measured emissions from real ovens before and after modifications. The third emission level chosen is the limit for ISM equipment in continental Europe (only the UK has the special provision between 886 and 906 MHz).

Table 3 presents data for an unmodified oven, producing emissions of 79 dBμV/m, 30 m from the building wall. Table 4 presents data for a modified oven which produces emissions of 55 dBμV/m, 30 m from the building wall. Table 5 presents data for a hypothetical oven operating elsewhere in Europe (where there is no ISM provision for the 886-906 MHz band), producing emissions of 40 dBμV/m, 30 m from the building wall. However, it should be noted that oven operators tend to choose the UK as a site for their operations because of the UK ISM provision. The UK oven manufacturer who collaborated in the project [1] was unaware of any similar ovens deployed in continental Europe.

For a number of values of the building – base-station separation d_μ, the interference field strength due to the oven and the total noise power at the base-station are calculated along with the reduced maximum mobile – base-station separation d_{mob}, as a percentage of the unperturbed separation, d_{mob0}.

Building – Base-station separation d_μ (m)	**Interference field strength at base-station due to oven (*oven noise*) (dBμV/m)**	***oven noise* + *base-station noise floor* power at base-station (dBm)**	**Maximum mobile – base-station separation relative to unperturbed distance d_{mob} / d_{mob0} (%)**
30	79	-44.2	1.3
60	70	-53.3	2.4
100	63	-59.9	3.7
200	54	-69.0	6.7
300	49	-74.2	10
600	40	-83.3	17
1000	33	-89.9	27
2000	24	-98.6	47
3000	19	-103.2	64
4000	15	-105.9	76
5000	12	-107.4	84
6000	10	-108.3	90
7000	8.0	-108.9	93
8000	6.2	-109.2	95

Table 3 - Results for an unmodified oven emitting at 79 dBμV/m, 30m distant from the building wall.

Building – Base-station separation d_μ (m)	**Interference field strength at base-station due to oven (*oven noise*) (dBμV/m)**	***oven noise* + *base-station noise floor* power at base-station (dBm)**	**Maximum mobile – base-station separation relative to unperturbed distance d_{mob} / d_{mob0} (%)**
30	55	-68.2	6.4
60	46	-77.3	12
100	39	-83.9	18
200	30	-92.9	32
300	25	-98.0	45
600	16	-105.4	74
1000	9	-108.5	91
2000	0	-109.8	99
3000	-5	-109.9	100

Table 4 - Results for a modified oven emitting at 55 dBμV/m, 30m distant from the building wall.

Building – Base-station separation d_{μ} (m)	**Interference field strength at base-station due to oven (*oven noise*) (dBµV/m)**	***oven noise* + *base-station noise floor* power at base-station (dBm)**	**Maximum mobile – base-station separation relative to unperturbed distance d_{mob} / d_{mob0} (%)**
30	40	-83.2	17
60	31	-92.2	31
100	24	-98.6	47
200	15	-105.9	76
300	10	-108.3	90
600	1	-109.8	98
1000	-6	-109.9	100

Table 5 - Results for a hypothetical continental oven emitting at 40 dBµV/m, 30m distant from the building wall.

Figure 2 presents these results in graphical form.

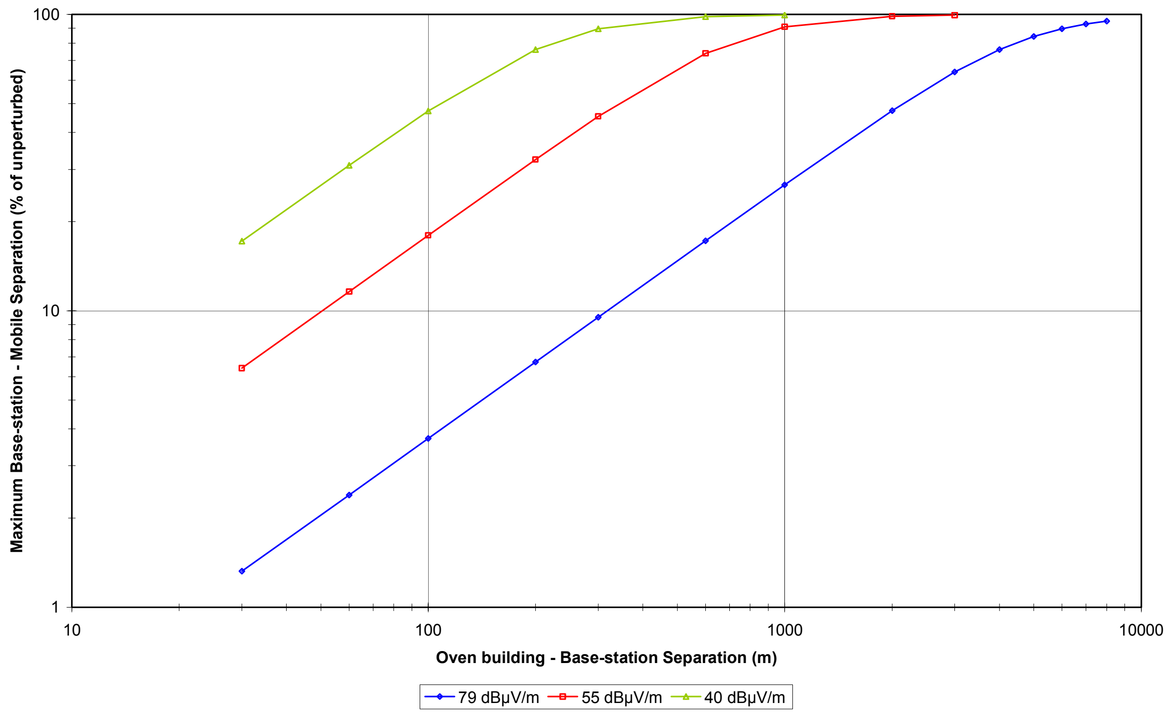

Figure 2 - Maximum mobile phone – base-station separation (%) as a function of oven-building – base-station separation.

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