The JRC Operations Advisory Group

Comments on the Radiocommunications Agency Report "Audit of Land Mobile Use in VHF Mid Band in the London Area"; RA285, of September 1996

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Contents

Introduction

The RA Report on the use of VHF Mid-Band in the London area suggested low usage of the JRC channel allocation, which led to sustained adverse comment by some sectors of PMR Industry. This paper examines some of the underlying assumptions and attempts to show why the true occupancy may be different to that suggested by the RA report.

The JRC VHF Private Mobile Radio band lies within what is described by the RA as "VHF Mid Band" and was the subject of a usage audit by the RA in 1995/96.

Mid Band is fragmentory in nature and contains various sub-divisions and other bands which are not covered by this Report, notably, the Amateur Radio 2 Metre band, the Home Office VHF and the VHF Marine Band are within this frequency range.

Most voice-based PMR activity in Mid-Band takes place in the upper end adjacent to VHF High Band with Paging Services and the JRC using the lower end of the band. Additionally, JRC Base stations are located outside the normal tuning range of equipment used in Mid-Band for normal PMR purposes, being essentially in the same spectrum as they were before Mid-Band was re-planned in the 1980s to clear mobiles out of VHF Broadcast Band II. JRC Equipment is also offset from the usual channel spacing raster by 6.25 kHz due to the proximity of bands using 25 kHz channel spacing.

Methodology used by the RA

The RA used computer controlled unattended monitoring equipment to gauge the occupancy of each Agency administered channel within the band. Details of the method are given in the "Overview" (Part 1) of the RA report, but the principles were:

- seven monitoring locations were used in an attempt to cover "....the majority of London within the M25...";
- scanning took place over a period of 13 weeks and the results were aggregated for the corresponding period each day;
- the coverage of the sites was based on a minimum field strength of 18dBuV/m, which the RA considered representative of 1uV at the antenna input of a "....typical PMR installation";
- both base and mobile frequencies for each Mid-Band channel were monitored.
- a scan rate of 20 channels per second was used.

Results obtained by the RA

The RA identified from a survey of licences that 38.2% of the Mid-Band channels were used in the London area by the utilities. Utilities also occupied 94% of all "National" channels. The RA published the raw data from their monitoring as Part 2 of their “Report”, although no conclusions were drawn.

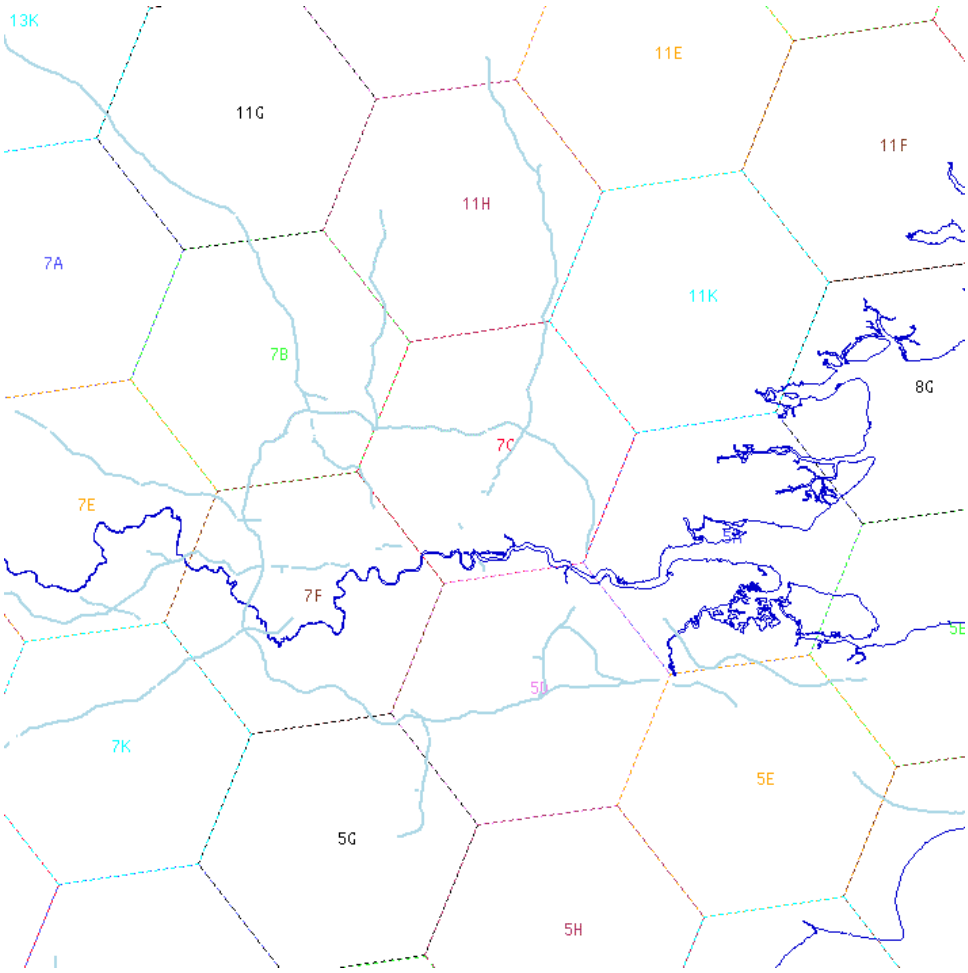
The data from the monitoring exercise indicated that some common base station channels were loaded to peak occupancies of up to 80% (eg common base channels 7 and 9), although many only peaked to around 40%. The existence of a few heavily loaded channels gave the RA some confidence in the monitoring. However, the JRC channels suggested generally low useage which was not consistent with what we would have expected.

JRC Scheme planning and the effect on recorded activity

The JRC VHF mobile radio systems are planned on an interference limited basis in a nine cell plan with 23 km radius cells and a 120 km channel repeat distance between cell centres (See JRC Cellular Map, Fig. 1). The planning rules require cells to be planned to a minimum signal level of -128 dBW, while the interference into co-channel cells must be planned such that less than 10% of the distant cell area receives unwanted signals greater than -147 dBW and no part of it has unwanted signals of greater than -138 dBW. Additional traffic capacity above that provided by the normal plan can be achieved by the use of 'inset' cells.

In planning the Electricity Industry Radio System, pressure on channels in the London basin led to some relaxation of the 19 dB JRC standard co-channel protection ratio by mutual agreement between companies, to a maximum interference level of -141 dBW in place of the more usual -148 dBW. This has allowed inset cells and cell boundary bending to be used to meet the predicted traffic levels.

Figure 1 - The South East England portion of the JRC Cellular Plan.



The Inset Cell technique

This technique re-uses channels from the two cells in the repeat pattern which do not have common boundaries with the cell in question. These 'inset' channels have generally to be operated at much reduced powers because the distance between operational areas is reduced down to 24 km. Their use has a knock-on effect on the design of the 'donor' cells - these too have to transmit at low powers.

The use of the interference limited plan and inset-derived channels has a number of effects that must be considered in evaluating the JRC use of its Mid-Band channels:

- many sites operate at low power levels to control interference within the plan; for example the main site in cell 7C runs at only 2W ERP;
- many sites utilise highly directional antennas for interference control;
- some sites have been included to solve very specific coverage problems, for example one Gas Industry base station was provided to deal with a coverage problem in the Old Kent Road and runs at 3 W with a Yagi antenna at 38 m asl using an inset channel, i.e. the channel is re-used within 23 km;
- dynamic mobile power reduction is used on many channels;
- the Gas Industry systems now use data to improve spectral efficiency, leading to short messages that may not be detected by the monitoring equipment.

Comments on results of the RA monitoring exercise

The JRC band schemes all use trunking with MPT1327 signalling. The Eastern Electricity (Eastern) system uses continuous control channels, which are time division multiplexed between sites where there is more than one site in a cell. In this document we shall use the Eastern Electricity system as it is representative of the kind of radio system used in JRC Mid-Band.

It would normally be expected that the control channels would show a high level of occupancy. The overall occupancy will be reduced if some sites in the control channel cluster are out of range of the monitoring station. The control channels therefore provide a good datum for calibration of the occupancy monitoring of the traffic channels in the system.

Expected traffic

In Eastern's system, multi-site cells can accommodate a maximum of six base stations. The number of time-slots spent by the control channel on each base station can be modified by changing the "activation sequence" but this is normally done to favour the prime site in the cell, to facilitate correct handling of vote-now commands by mobiles nearing the cell boundary. This means that for a control channel the worst case channel loading, where the monitor station can only hear one of the stations in a cell, is 17%.

Measured traffic

The activity recorded at Stanmore for channel N2 (National 2 in the Mid-Band Report, Part 2) in cell 7B (see Map, Fig. 1) shows a level close to what would be expected for a five site cell of which only one base station is in range of the monitoring equipment. Channel N3 in cell 7C should show identical characteristics but the traffic is lower than expected. For channel N6 the monitoring did not detect any appreciable activity, although the channel is used for control purposes in cell 5A. It is noted that only Stanmore detected channel N3, despite its use as a control channel throughout cell 7C, including at Harold Hill which is less than five miles from the monitor site at Romford.

Although details are not provided in this paper, similar anomalies are noted in the activity monitored on the channels used by the Gas Industry.

Specific examples

In order to obtain some feeling for the efficacy of the monitoring process, a comparison was made between the measured and expected traffic for the channels used by the Eastern Electricity system. The cells used by Eastern that were studied were 5A, 7B and 7C. The results of the RA monitoring for these cells are as shown in the following table. The table

gives the information shown by the RA graphs for the channels used in the cells under the sites for which they are mentioned. The activity recorded by the site showing the greatest traffic has been used in compiling this table. It is noted that although some sites are shown as having recorded activity it was so low that it appears as zero on the activity graphs.

Table 1: Results of RA monitoring of channels used in cells 5A, 7B & 7C

Cell	RA National Channel Number (JRC #)	Monitor Location	Mean Occupancy (%)	Peak Occupancy (%)	Remarks
7B	N2 (23)	Stanmore	15	20	control channel
7B	N20 (41)	Stanmore	5	10	bursts to 20% loading
7B	N11 (32)	Stanmore	5	<10	
7B	N29 (50)	Stanmore	5	15	
7B	N37 (58)	all	0	0	used only at Cheddington
7C	N3 (24)	Stanmore	10	15	control channel
7C	N12 (33)	Stanmore	10	20	
7C	N21 (42)	Stanmore	5	<10	
7C	N30 (51)	Stanmore	<5		
5A	N7 (28)	Stanmore	<<5		
5A	N37 (58)	Banstead	0	0	Tilbury only, low power
5A	N6 (27)	Stanmore	0	<5	control channel
5A	N15 (36)	Stanmore	0	<<5	
5A	N17 (38)	Banstead	0	0	
5A	N47 (68)	Stanmore	10	20	
5A	N24 (45)	Stanmore	<<5	10	Hadleigh south, low power
5A	N33 (54)	Stanmore	<<5		Hadleigh south, low power

Note: The remarks in the above table show that some channels are used at low power, sometimes with directional antennas, to avoid interference to other JRC services and to adhere to the interference limited cellular plan.

Interference

There is a remarkable similarity between the traffic patterns for many of the channels monitored by Stanmore, one of the more active sites used for the survey. These similarities are particularly apparent where the channel is "assigned to user outside of audit area but within interference range of London" and hence has a lower signal level at the monitoring receiver than for systems where the monitor station is within the primary service area. This is possibly suggestive of the activity being the result of some local interference that is sufficient to mask weak signals from the user systems that were intended to be monitored. This has been referred to as the "Stanmore Effect", although the Mid-Band Report, Part 2 has examples of this effect on other sites which may indicate a problem with the basic design of the monitoring equipment or perhaps their siting. It has been noted that the monitoring equipment was sited in locations all of which are

owned by the same organisation, so it is quite possible that the effect has some link to their activities in the evenings.

Conclusions

An initial analysis using probability theory suggested that there was a strong probability that the monitoring system would not record activity accurately on control channels, because it would miss the short bursts of activity on a channel that was time division multiplexed among sites. However the presence among the results of some measurements that can be explained in terms of the expected traffic gives a level of confidence in the sampling procedures. This means that the unexplained lack of traffic must be because of poor radio frequency sensitivity of the monitoring systems. It appears that some sites may also have been affected by local interference, which would falsify the results.

Possibilities for use of JRC channels in London by third parties

The results of the monitoring survey may have lead to a false impression that JRC Mid-Band channels are available for other users in Central London. The reasons why this impression is erroneous are as follows:

- any take-up of so-called 'unused' channels within London would need to be co-ordinated within the JRC plan. This would mean users would have to plan their systems to restrict exported interference within the JRC plan to protect existing systems;
- in addition, users would also have to accept interference up to -147dBW within the JRC cells designated for the use of those channels and at any level in areas outside the JRC plan. JRC systems have only been planned to protect designated cells within the JRC cellular plan.

The comments on the monitoring study should show that channels cannot be assumed to be interference free just because they showed low traffic in the audit. It is not expected that use of the channels in conformity with the JRC planning rules would be commercially attractive to wide-area PMR or common base station operators, for instance.

An example of the use of a typical JRC mid-band channel used by the electricity industry in the London Area is shown in the picture below, taken from the JRC coverage planning and assignment tool. This clearly shows the cellular plan and the coverage and interference areas. In the picture, the yellow area covering Central London is receiving interference levels of up to -147dBW. The purple and blue areas are receiving interference in the range -128dBW to -147dBW, and the green areas are the actual coverage areas of the base stations, where wanted signals are above -118dBW. It would be necessary for any operator in London to protect the cells shown on this plot as containing base stations so that the whole cell did not receive interference in excess of -147dBW on this channel and any others used in the cell. Although the North Thames Local Delivery Zone (LDZ) primarily uses UHF, other LDZs in the London area use mid-band, and a typical usage plot is given in Figure 3.

Figure 2: A typical ESI channel in London.

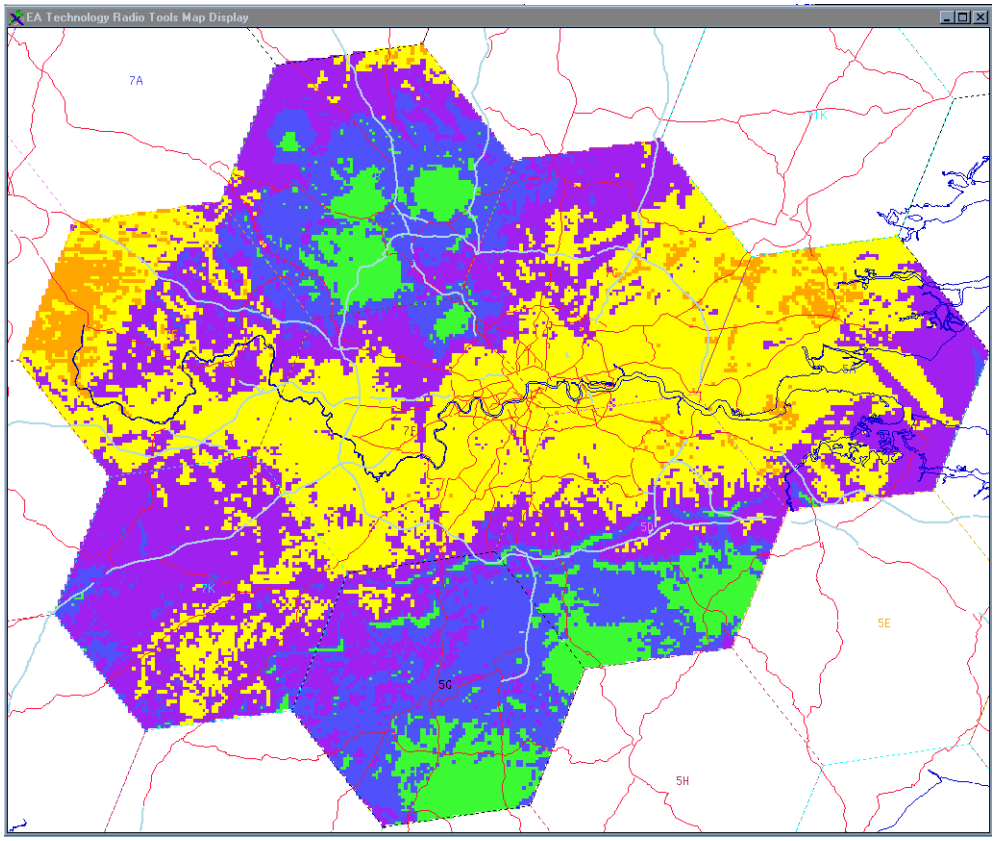
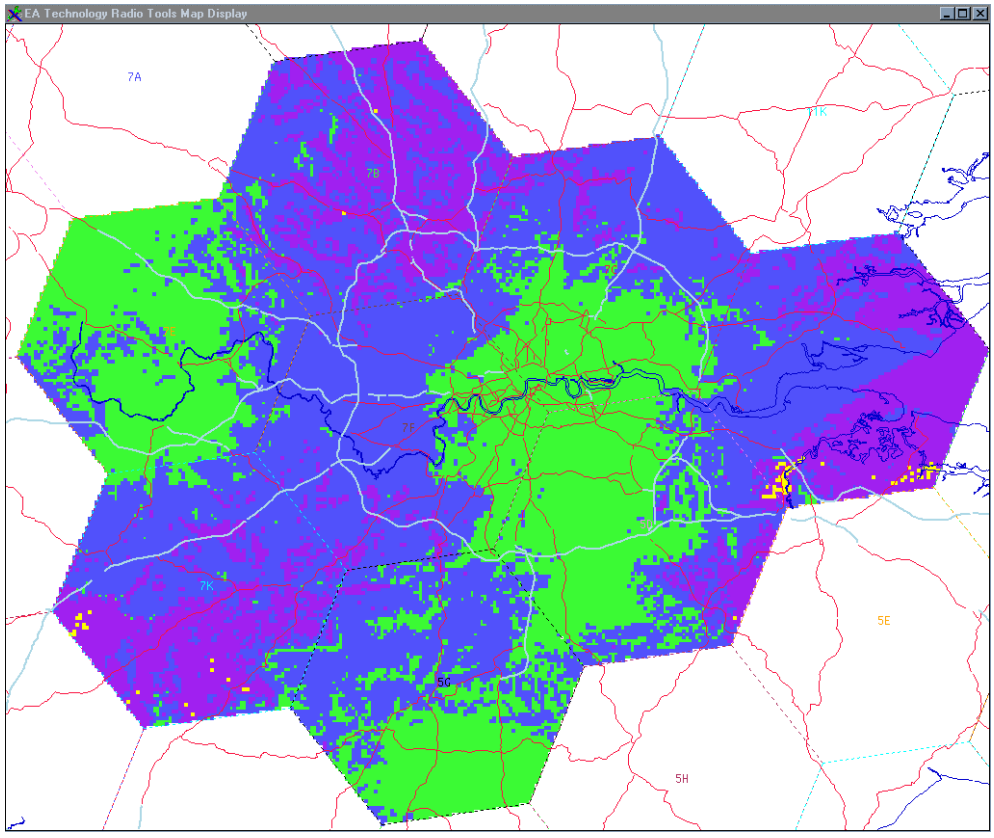


Figure 3: A typical gas industry channel re-use in the London area.



Comparison of some system parameters

The following chart shows a comparison of the philosophy of use of by Common Base Station operators against JRC operation. It can be seen that the JRC operation is more efficient in terms of spectrum use due to the use of trunking techniques and an interference limited cellular plan. This spectral efficiency is necessary to support vital utility services within the limited radio spectrum available to the JRC and is achieved at the price of the system complexity associated with multi-base station working with low ERPs, low antenna positions and highly directional antenna systems. Further spectral efficiency is also achieved in the Gas Industry by the extensive use of data transmission to replace voice for job dispatching.

Table 2 - Comparison of some system parameters.

Item	Utilities	CBS	Notes
average licensed base ERP	12.3W	24.4W	
Average base station coverage area	cell size is 1662km^2 but most cells have multiple base stations	All but two sites cover the whole of the London Area - c3183km^2	
Average channel re-use nationally.	56 (max = 95)	7	
Erlangs/km^2 per channel	940μErlang/km^2	68 μErlang/km^2	Theoretical capacity, using typical call length and GOS.
Average number of base stations per channel in survey area	2.59	1.04	
Percentage of available channels used in survey area	80.2%	64%	
Base station sites in survey area	39	25	
Average number of services per channel	2.12	0.66	Source - occupancy pages, RA285 overview

Conclusions

This paper shows that the usage of channels within the JRC band is very well managed and is indicative of the vast amount of RF planning and infrastructure investment that the joint industries have placed in their radio network.

It can be seen that low power base stations allow a far higher reuse of frequencies than traditional high PMR sites. The reuse of channels is typically eight times greater than that achieved by CBS operators, for instance.

The JRC Band systems show the way forward for others who are short of spectrum and demonstrates that much can be made by proper RF planning. This, of course, has financial implications for the operators but it is a necessary expense if efficient reuse of spectrum is a consideration.

The audit was efficient in detecting the use of channels by traditional hilltop base stations, but in the future, where channel interleaving, low power base stations, inset channels and digital communications are used to minimise call waiting and maximise information flow, it would be preferable if the operators and the Radiocommunications Agency were to work closely to discuss audits before they took place.