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ELECTROMAGNETIC NOISE MONITORING

W E L L I N G T O N

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INTRODUCTION

It is difficult today to imagine life in a world without electrical or electronic appliances. Every year sees the increased usage of electronics in office machines, household appliances, toys, transport, communications and industry. The advantages provided by the use of such electronic devices are readily apparent. For example electronic engine management devices are now common in motor vehicles, making possible greater fuel efficiency and reduced toxic exhaust emissions. Many power tools and household appliances have electronic controls giving improved utility to such devices, and few would argue against the usefulness of computers and modern telecommunications devices such as cellular phones or pagers.

However, like most good things there can also be a down side. All electrical or electronic devices, regardless of how well they are designed, manufactured or maintained, generate electro-magnetic emissions as a by-product of their designed function when being used. These unwanted emissions not only affect the efficiency of the device in terms of wasted energy, but can also affect the proper operation of other electronic devices. Such emissions are readily observable on a TV set when an appliance which is not properly “suppressed” causes visible interference to the picture. A much more serious example is losing control over a car when its microprocessor gets affected by strong unwanted signals, causing its ABS braking system to lock up, or its safety air bags to deploy.

Although much can be done to reduce the impact of interference in such specific instances, in many cases the interference is not so readily observable. Intermittent malfunctions in otherwise reliable equipment is sometimes found to be caused by unwanted or spurious emissions from nearby equipment.

Possibly of even greater concern in the longer term is the contribution all unwanted electromagnetic emissions make to the latent background noise floor. Interference which is great enough to cause observable problems is usually eventually tracked down and suppressed to the point were it is no longer a significant problem. However, other emissions which, either because of their low magnitude or limited frequency bandwidth, do not immediately cause an observable problem, over time add to the natural background noise floor until services operating at very low signal levels are gradually “swamped” by the noise. For example, the recent power cuts in Auckland enabled some remarkable measurements to be taken. The noise floor measured in a typical land mobile band at 100 MHz was measured and at some locations was found to be 36 dB (that is 64 times, in terms of voltage) below readings taken a few months before the power cuts. During the power cuts, the averaged reading at a sample of CBD sites was between -114 and -117 dBm. Many land mobile services regularly work with wanted signals of this order, which indicates that such services must be operating under some stress when the power supply to Auckland’s CBD is operating normally.

Another example is TV reception. The noise field strength measured in Auckland CBD while the power supply was operating normally was 20 dBμV/m in band one. For good reception it is necessary that the wanted signal is at least 35-40 dB above any noise – in this case 55-60 dBμV/m would be required, which is higher than the currently protected level of 48 dBµV/m. That means that weaker TV signals, though above the set minimum level, may suffer severe interference.

Such findings show the need for regular checks to be made of the noise floor so that overall trends can be monitored. It may be that at some time in the future many of the radio based services we take for granted today may be significantly impaired or even rendered inoperative if the noise floor exceeds their operating limits. It is also possible that many other electronic devices will also suffer.

To combat such an eventuality “EMC” measures will need to be reviewed as will the immunity to interference specifications for radio and electronic equipment need to be considered. The attached report gives the findings of an initial noise floor measurement programme. Such a programme needs to be continued on an ongoing basis with measurements taken at regular intervals if the maximum benefits are to be obtained.

Katharine Moody

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Ministry of Commerce

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EM NOISE REPORT GLOSSARY

AM	Amplitude modulation
CBD	Central Business District
CDMA	Code Division Multiple Access
CISPR	International Special Committee on Radio Interference
CTO	Chief Technical Officer, Ministry of Commerce
dB	decibel
EM	Electromagnetic
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
F/S	Field Strength
FM	Frequency modulation
GHz	Gigahertz
GSM	Global System for Mobile Communications
IF	Intermediate Frequency
ITU	International Telecommunications Union
kHz	Kilohertz
L/M	Landmobile
MF	Medium Frequency
MHz	Megahertz
MR	Management Right
ms	millisecond
NFT	Noise Floor Team
PC	Personal Computer
RF	Radio Frequency
SINAD	Ratio of signal with noise & distortion to noise & distortion (the 1kHz signal is measured **pre** and **post** notch filter)
TETRA	Trans European Trunked Radio Access
UHF	Ultra High Frequency
VHF	Very High Frequency

EM NOISE MONITORING TEAM REPORT

June 1996 – December 1997

(Latest Update March 1998)

This report presents findings of the team formed to investigate electromagnetic (EM) noise, its effects and methods of monitoring. The primary task of the Team was to assess whether there is a need for monitoring noise in the long term as well as the risks of not doing so. The report was originally submitted to the Radio Spectrum Management Group of the Ministry of Commerce as an “internal” investigation into methodology and equipment suitable for EM noise measurements.

The report marked successful end of the investigation phase of the project, and management decision on the future monitoring programme is awaited.

Due to commercial sensitivity, when adapting the original report into this brochure the references to actual equipment brands have been deleted as much as practically possible.

The conclusions and recommendations of the report are that of the Team and are not intended to favour or discredit any equipment manufacturer. The statements regarding equipment quality and suitability refer only to the particular purpose of EM noise measurement, as the Team has found it.

The Noise Floor Team are (in alphabetical order):

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Alexandra Preskar Manich – Wellington

This booklet is published on the Ministry of Commerce, Radio Spectrum Management Web site:
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1. EXECUTIVE SUMMARY

There has long been a concern in telecommunications industry that the electromagnetic (EM) pollution or “noise” is rising. To investigate the matter, Ministry of Commerce initiated a project to set up a programme to monitor the level of unwanted emissions, and this is the Noise Floor Team’s (NFT) scoping report.

Many examples of EM pollution may be seen every day, originating anywhere from TV/radio transmitters, mobile phones, car engines, to children’s toys or washing machines. Devices affected by noise may not respond to the signals they receive because those signals get distorted or attenuated; or, devices may receive some unwanted signals they recognise as “wanted” and perform undesirably. Uncontrolled emissions may eventually make some parts of the frequency spectrum unusable, so it is very important that the levels of pollution are monitored and some action taken if they rise above the tolerable limit. Even the currently allowed emission limits for devices may be too high, and this project will collect and analyse the data and investigate possible solutions.

The goal of the project is to set up a programme to obtain information on the levels and sources of man made electromagnetic noise and its variation over time, as it affects radiocommunications.

Benefits of this project are manyfold**.** With information available as to what parts of the radio spectrum are “noisiest”, it may be possible to more accurately align critical radio services into frequencies which are the least noisy. With fixed link planning, the necessary minimum level of received signal to provide reliable service can be accurately assessed. The geographical spread of “noisy” areas would also be useful information for planning broadcast, cellular and radiotelephone services.

Current standards on EMC (electromagnetic compatibility) will also benefit from comprehensive information on measured EM noise and it will be possible to monitor their efficiency in the longer term.

The first action of the Noise Floor Team was to carry out an **industry survey**, which confirmed our concern of the rising EM noise floor and expressed almost **unanimous support for the project**. The industry believes that many existing and new radio services may be affected by the rising EM pollution and that a project like this is necessary to determine and monitor the level of pollution. This would enable the Ministry to maintain the overall value and utility of the radio spectrum resource and to ascertain that the power floor and adjacent frequency emission limits for the new management rights (MR) are appropriate to the environment in which services licensed under the MR will operate.

The team has conducted trial measurements in Auckland and found that the level of unwanted emissions may already be high enough to affect existing radio services. Similar results were obtained in Wellington. Repeated measurements in Auckland CBD during the recent power cuts show significant drop in EM noise levels (up to 36 dB), which confirms the perception that the cumulative effect of a number of electrical and electronic equipment is among the main causes of EM noise. This justifies the need for a long term monitoring project, using the best equipment available. As spectrum users’ equipment is becoming more and more sensitive, a high standard of noise floor measuring equipment will be required to provide credible results.

Equipment and methodology to be used for measurements have therefore to be carefully selected. The team has looked at a number of receiver and spectrum analyser options and has striven to identify all the requirements and practical limitations of the long term monitoring process. We have come to the conclusion that one of the test or EMI receivers would be the most suitable for the project. In the **recommendations of this report** we are presenting the options which can satisfy the minimum requirements of the project. We endeavoured to offer the options in a wide pricing range and have included in the report only what we have found to be the representative member of each receiver and pricing “class”. The list is however not exhaustive and there may be other receivers with similar characteristics for similar price available. This is particularly true as new receiver families are being introduced by the world’s leading manufacturers.

Management approval has been sought for the purchase of one of the receivers and antenna systems presented hereafter.

2. ELECTROMAGNETIC NOISE – THE POWER OF THE DARK SIDE

What is electromagnetic noise and why is it proclaimed dangerous and unwanted?
This extract from Ministry of Commerce's Field Offices newsletter is a graphic example of EM noise and interference (EMI) it may cause.

"… A not so long time ago in a district not so far away, a certain Technical Officer's son received a Darth Vader remote control toy for Christmas. The parents noted that this toy displays the renowned C-Tick for EM compatibility (EMC)! The children played Star Wars games until the sun set.

And that's when the real story began. You see, once the children were in bed at night, the parents could hear the occasional synthesised sound of "**You underestimate the power of the dark side!**". A quick check revealed all children asleep and the remote control untouched. Once a number of these occurrences has been heard, an "interference investigation" was launched. The Technical Officer called himself back on duty and quickly found that the darned toy operated at 27.120 MHz and responded to electrical noise! This EMI could be generated from such simple things as light switches being turned off, and washing machine pumps switching off during normal wash cycles… "

Unwanted signals received by a device can cause it to operate in a strange way or to stop operating unexpectedly when it may even be dangerous. While the above example sounds funny and amusing, there are others that are anything but. We heard a story of a man who was driving down the highway when suddenly his brakes locked. The reason – he had turned on his mobile phone and the signal generated by it affected his car's computer which applied the brakes ! The poor guy could only wave goodbye…

In both examples the device received signals that were strong enough to turn on some processes in it, when those signals should've been recognised as unwanted and ignored or shouldn't have been there in the first place. They are just wavelets in the ocean of electromagnetic noise that surrounds us.

Another common example of RF pollution is local oscillator leakage. All modern receivers use the signal from the "local oscillator" to convert the incoming broadcast signal to a frequency suitable for further processing in the receiver. Quite often cheaper receivers have no filter which would suppress the local oscillator's signal, so it travels back to the receiver's antenna and gets radiated, like from a transmitter. The frequency of that signal is usually 10.7 MHz higher than the wanted FM broadcast signal, which means the services normally operating in the band 99 – 119 MHz will be heavily affected if they are in the proximity of such a receiver (may be up to 1 km).

The EM noise ocean is surely getting more and more stormy every day. Waves peaking high up from its surface cause occasional blips and effects like the ones described above. But even more worrying is the fact that the ocean's level is constantly rising! That is, the overall mixture of both wanted and unwanted signals is adding energy to the usable frequency spectrum.

In some ways the situation is similar to a man on the beach. While the ocean level is behind the beach line, he is safe. As the tide comes in , it approaches his feet first and slowly soaks his legs. The person may stay where he is or step back. If he stays, the rising tide will eventually drown him; if he goes back, there is only so much space for him to withdraw in order to stay dry. And if the tide continues to rise, all his efforts may be fruitless. The best action would be to stop or control the tide. The same stands for EM noise: we have to know how high it is, whether it presents a danger and if so, take some corrective measures.

Very little electronic equipment will remain unaffected if exposed to high EM fields. In one of the examples mentioned above, a mobile phone caused interference to car electronics. However, mobile phones themselves will be (and already are) among the first victims of EM noise. They will suffer reduced coverage, poorer reception quality… To counteract that, more cellular sites/ base stations may have to be erected, increasing the underlying EM levels and creating the further need to increase the power of wanted signals for mobiles.

What does it mean for an average cellphone user? The power of the transmitter in the hand-held phone will have to increase – possibly to the level that poses danger to human health, being so close to the head.

It is unlikely that high EM levels per se can cause other health hazards, but rather hazards may come from undesired responses by devices which are not intended to receive radio signals, like the case with car electronics. Those responses should be known and such devices operated under specified conditions. That is why the standards relating to electromagnetic interference (EMI) and compatibility (EMC) are set internationally and New Zealand follows them. Measurement of EM noise is among the few tools we have for determining the actual levels of EM “dirt” in environment and compliance (or otherwise) of equipment with the standards. The noise floor project would be useful as a measuring stick to ascertain the degree of change resulting from those regulatory measures.

2.1. Summary of Effects of EM Noise

The primary effect of radio “noise” is blocking of reception of desired radio signals in apparatus needing those signals for their correct operation. This translates to reduced coverage area or transmission distance from the transmitter to associated receiver(s) for acceptable quality of signal, or reliability of operation. Practically, users won’t be able to use their mobile phones or radio/TV receivers at places where they previously could. To alleviate this, for many radio services it would require more or higher-powered transmitters to achieve the desired or necessary coverage, with the possibility of further raising noise floors in an increasing spiral.

Examples within the home may be that in “high noise” areas, the number of viewers/ listeners who can achieve acceptable reception of their desired programs will be fewer than in “low noise” areas, cordless phones may have shorter range around the house, garage door controllers may only work when close to the door etc… For users of radiotelephone services, including cellular telephones, reduced coverage and poor quality reception will be evident. The number of devices using radio receivers which are part of everyday life is steadily increasing and includes things like wireless doorbells, security systems, baby minders, medical alert calls, intercoms, and remote-controlled audio systems. An exhaustive list would be impractical to include here, but most of Restricted Radiation Devices (Specification RFS29) will be affected by ambient radio “noise” levels.

2.2. Why Measure – Purpose of Noise Floor Measurements

The emission limits are largely set by international standards such as EMC requirements. As most electronic equipment in NZ is sourced overseas it is not likely nor is it desirable that New Zealand impose standards that are tighter than its trading partners. The main use of the Noise Floor project will be to measure the effectiveness (or otherwise) of the regulatory regime as it exists now, and as it will be in the future, as new standards get adopted.

One of the many benefits which might result from comprehensive noise floor measurements – if the results are made available as part of any specification for parts of the spectrum being "sold" by the Ministry – could be a certain amount of protection (for the Ministry or its officers) from any claim that a piece of spectrum is unfit for particular purpose because of unexpectedly high noise floors. Provision of noise floor information should not be to say what a user can or cannot do with their spectrum, but to be open and honest at an early stage to create an awareness of electromagnetic compatibility issues. It would be up to the would-be purchaser to decide from the measurements available as to whether the piece of spectrum under consideration would fulfil its intended use, before making the purchase.

There would also be engineering benefits (to the Ministry and other organisations involved in radio planning) of knowing what existing noise floor levels are at specific sites. By continuing noise floor measurements, the effect on levels of changes such as varying transmitter powers and frequencies at those sites could be determined. This would be especially useful if it is necessary to confirm or reject claims that some transmitters are causing health and/or other problems.

Another item which is necessary for localised control of noise floors are sound engineering principles for separation of services, spatially and frequency-wise, to minimise inter-modulation problems, both in transmitters and receivers. The noise floor project and resulting information will be the only effective way of monitoring the results of these things (other than by compiling statistics as to the number and localities of interference complaints related to blocking/intermodulation etc.).

Other possible uses of the future noise measurement data could be as a supplement and input to studies on biological effects of electromagnetic radiation. Even though this project concentrates on very low levels of radiation, in the absence of any "wanted' signal – in contrast to the measurement of usually high EM field levels in the proximity of a transmitter – data on levels and annual variation (if any) of background noise could be added to other numerous factors in an environmental research.

2.3. What Next?

It seems that if high noise floors are measured, it indicates a need for more compliance action. This would be best achieved by work in the field detecting non compliant equipment and then enforcing regulations. It would be possible to make examples of non compliance by forcing the removal of interfering equipment from sale, for example. Issuing infringement notices could also be an effective way of enforcing compliance.

Another way of looking at radio spectrum can be to view it a bit like property or land. It is subdivided according to need and the need varies so that areas or bands are used for different services. When somebody buys a house, the local council produces a Land Information Memorandum containing details about land use, natural threats, easements etc. There are things like flooding hazard ratings, wind ratings, improvements, permits and services.

The Ministry might be seen to be a bit like the local district council (we already subdivide, zone and charge rates) and go the further step of providing a Spectrum Information Memorandum, offering information about possible constraints to be expected in the nominated spectrum as a result of noise floor measurements made: expected noise floor, EMI hazards, incumbents, adjacent spectrum property particulars (with spurious emission and blocking parameters in mind), propagation effects – empirical and measured.

From the legal point of view, there is currently sufficient legislation in place to control noise floors (and has been since the Interference Notice legislation of 1934) through the mechanism of specifying unwanted or interfering emission levels. The legislation has provided for levels of unwanted emissions to be complied with by any apparatus for the past 65 years or so, previously under a Type Approval system, and most recently under a Declaration of Conformity system.

Because the existing legislation controlling unwanted radio emissions (primarily the Declaration of Conformity system) is very firmly tied into international standards, it is highly unlikely that New Zealand would impose different standards, although the results may be a useful measure of the success or otherwise of those standards. However, noise floor information is a very necessary planning tool to help ensure that radio services (including Restricted Radiation apparatus and equipment covered under General Licence) are optimally positioned in the radio spectrum, and also geographically.

Because of New Zealand's very high rate of radio frequency spectrum usage and lack of other noise measurement projects in the world, the comprehensive results of noise floor measurements may be useful in any attempts to gain international approval for changes through organisations such as the ITU or CISPR.

3. PROJECT BACKGROUND

Due to the concern that the pollution of the electromagnetic spectrum is rising, Ministry of Commerce formed a team to investigate and monitor the level of unwanted emissions ("noise"). The team initially met on 12 June 1996 where it was resolved that the goal of the project was:

To set up a programme to obtain information on the levels and sources of man made electromagnetic noise and its variation over time, as it affects radiocommunications.

It was agreed that to do that, measurements are necessary at a number of frequencies throughout the spectrum. The most important parameter for describing the unwanted emissions is the so called noise floor, which is the underlying level of the electromagnetic signals in the environment. Noise floor measurements are envisioned as a long term process, meaning that the measurements would be carried out at regular intervals, all year round (two to four times a year), at selected sites nationwide. It is expected that it will become an on-going monitoring process.

3.1. Industry View

The noise floor being such an important parameter, measurements should be made at a variety of sites to reflect the different types of radio reception situations found in practical use, such as:

	- Domestic - Industrial - Business
Multi User	- Landmobile - Fixed - Broadcast
Reference	- Remote site with low noise levels that are unlikely to change

It was decided to first carry out a survey of radio spectrum users to ascertain if the industry agreed with our perception that the noise floor is rising. The users would have the opportunity to express what effects they think this may have over time and to contribute in any other way they find appropriate.

A questionnaire was sent to approximately two hundred industry representatives between October 1996 and January 1997. A copy of the questionnaire is attached as Appendix 1.

A return of about fifty percent of the questionnaires was received by early February 1997, the results of which were analysed and are summarised as follows:

Ninety five percent of the replies showed that the respondents were concerned that the RF noise floor was rising. Land mobile and fixed radio services were perceived to be the most likely to be affected.

The replies suggest that any measurement programme should be conducted over a wide range of frequencies and a variety of areas, particularly industrial, commercial and hill top radio sites.

The results also indicate that there is some concern that there should be more checks to ensure that radio transmitters, information technology equipment and other interfering equipment comply with licence and specification conditions.

The full results are attached in Appendix 2.

The response from the industry indicates that problems associated with rising noise floors are expected to increase. These problems are aggravated by the increasing trend for service providers to operate very sensitive receivers with preamplifiers, and may result in effects such as reduced coverage of mobile communications systems requiring additional transmission sites and a consequent impact on the availability of frequency assignments. Higher intrinsic level of field strengths requires higher power levels for wanted services, resulting in yet higher intrinsic fields and increasing danger of interference. For these reasons it is considered that the monitoring of the noise floor at various locations may assist in predicting these effects.

4. BENEFITS FROM THE PROJECT

Electromagnetic noise measurement project would provide manifold benefits to the Ministry and the industry. The project as it is envisaged by the team will be technology neutral, yet comprehensive enough to provide for different technologies in operation – today and in the future.

That is, measurements would be taken using at least two detectors, in two or three IF bandwidths and then extrapolated to the wider IF range. So far, trial measurements show a great degree of agreement with the known formulas. That data would be made available to the interested parties, so various users could easily calculate the possible impact of EM pollution on their services. However, measurements on request would also be considered.

Theoretically, in order to investigate the effects of noise on different services, the way the measurement is taken should vary depending on the use of that part of the spectrum. Services like GSM, TETRA, CDMA, Broadcast Radio etc., all respond differently to a particular type of interference or noise level. The characteristics of the noise will also affect a particular service differently. For example, a digital service may be immune to pulsed noise which will disrupt AM or FM analogue services.

Future spectrum usage may, however, be completely different from the one today, and no matter how useful one technology-dependent measurement may be today, the data collected that way may become obsolete and impossible to compare with other type of measurements in the future, like comparing apples and oranges.

That is why the team is planning to carry out measurements in a number of preselected bandwidths in all frequency bands, using the most common detectors (average, peak and possibly rms), so that the database will contain largely the same type of data for all of the spectrum. Most existing and future services will be covered that way. Band managers would have access to the database, and could choose the data which will most closely match their particular service. Trends in this data over time will give them a pretty clear idea of the level of spectrum pollution and its effects.

As for the Ministry, the objectives of making noise measurements are:

1 Ascertaining that the power floor and adjacent frequency emission limits (AFEL's) applied at the time Management Rights are created are appropriate to the environment in which services licensed under the MR will operate

2 Maintaining the overall value and utility of the radio spectrum resource by monitoring any deterioration in EM pollution levels.

3 Monitoring effectiveness of the standards adopted, in relation to the underlying EM levels.

It would also allow the Ministry to build credibility with bidders for, and occupiers of, the spectrum, that it is adding value. For the bidders, we could provide graphic proof that the spectrum is clean and usable for that service, and for the occupiers, they can use the data to ensure they can continue to run their service competitively as the spectrum becomes more occupied.

5. TEAM'S ACTIONS

There have been extensive discussions and research into equipment which may be suitable for carrying out noise floor measurements. It seems that there are a number of receivers which may be satisfactory. Initial equipment specification framework was put as follows:

Frequency Range:	500 kHz – 3 GHz (20 MHz – 1 GHz minimum)
Dynamic Range:	Capable of measuring to -20 dBμV (-125 – -120 dBm)
Detectors :	For average & peak measurements; rms would be desirable
IF Bandwidth:	3 kHz, 10 kHz, 25 kHz, 120 kHz, depending on frequency
Intermod. Distortion:	Capable of operation at high power TV/BC transmission sites
Power Supply:	230 V AC. 12 V DC operation would be useful
Interface:	• Has in-built processor OR • Capable of interface with PC for programming changes of frequency/bandwidth with time. • Storage of results for analysis. • Possible remote operation/programming via modem.
Antenna systems:	• Must be robust – able to stand weather extremes and transport • Reasonably portable • Not prone to overloading by strong signals • Able to be fixed in exactly the same position for successive measurement at same site • Common mounting at all sites • Must be largely omnidirectional at frequencies to be measured. That can be obtained either by using one omnidirectional antenna (which is practically difficult), or by means of combined antennas, giving an omnidirectional radiation pattern, • Calibrated, i.e. K factor curves available.

In order to progress definition of equipment, the team undertook trial measurements with the equipment available within the Ministry.

5.1. Trial Measurements

August 1997

On 28 and 29 August 1997 the team conducted some trial noise floor measurements at selected sites in the Auckland area. The purpose of these measurements was primarily to establish if measurements could be made using equipment already in use in the Ministry, to test the methodology and to find out possible unpredicted problems connected with the measurements.

The sites selected were representative of industrial commercial, residential and relatively quiet areas.

A complete report on these measurements is attached as Appendix 3.

This exercise confirmed that the Rohde & Schwarz ESVS 10 noise measuring receiver or the like (with disk drive and programming abilities) would be satisfactory for conducting noise floor measurements.

The measurements indicate that the noise floor level varies at different locations and is higher in industrial and commercial areas.

These levels may already be high enough to affect radio services, as illustrated by the following examples

Example One

At the Auckland Field Office at 150 MHz using a 10 kHz IF bandwidth and 500 ms measurement time, 0.5 dBµV (average) was measured directly off the horizontally polarised half-wave dipole.

0.5 dBµV = -106.5 dBm = 1.06 µV

Typical receiver mute settings at 150 MHz (E band) frequencies are -117 dBm or lower. To avoid interference at this location, mute settings would have to be adjusted to above -106.5 dBm, effectively reducing the mobile coverage area.

Example Two

At the Auckland Field Office at 72 MHz using 120 kHz IF bandwidth, 14.1 dBµV was measured directly off the horizontally polarised half wave dipole.

14.1 dBµV = -92.9 dBm = 5.07 µV

That equates to the field strength (F/S) of 20 dBµV/m.

With television reception, the television signal must be at least 35-40 dB above any noise to obtain an interference (noise) free picture. In this case any band one television signal below

55-60 dBµV/m or 49-54 dBµV (500 µV) would be affected by interference. The minimum protected level for band one currently is 48 dBµV/m, which means that noise may already be affecting good reception.

The measurement results are presented in a form of graphs in Figures 1 and 2.

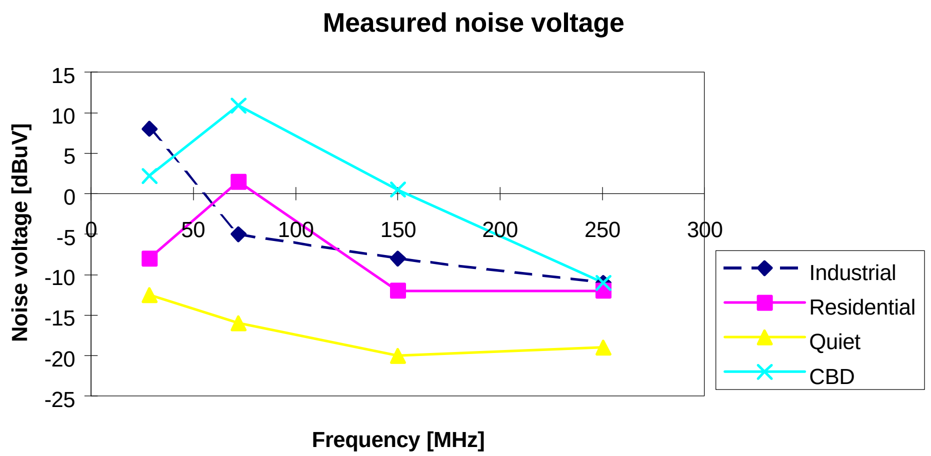

Figure 1 *Average noise voltage measured in different environments, using the receiver with 10 kHz IF bandwidth and 500 ms measurement time*

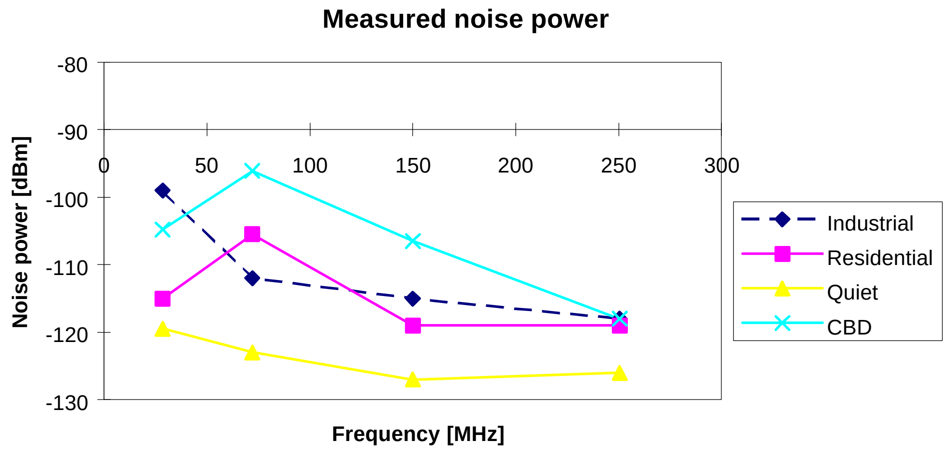

Figure 2 *Average noise power measured in different environments, using the receiver with 10 kHz IF bandwidth and 500 ms measurement time*

Some measurements conducted for the purposes of landmobile communications in Auckland and Wellington areas during September 1997 also show a very high level of electromagnetic pollution.

March 1998

In February Auckland experienced serious power crisis and large parts of the CBD were left without power for some time. Many businesses have temporarily closed or relocated, leaving fewer PC's, microwave ovens, fax machines and other equipment operating. The NFT repeated EM noise measurements at the same sites as in September 97 (for another related project) and obtained very worrying results.

Measurements were done using average and peak detector, in 9 kHz (CISPR16) IF bandwidth. Frequencies to measure were 80.5 and 101.5 MHz (A and B band).

The results show great drop in noise levels: sites in Queen Street are up to 36 dB quieter, when using peak detector in a receiver! Most of the sites showed reduction between 8 and 20 dB. When using the average detector, reduction of between two and seven dB was obtained. It was only when the power was cut, that the EM power received at some sites came down to between -114 and -117 dBm (average), which is necessary for normal operation of the landmobile services, for example.

The table with full measurement results is attached as Appendix 4, and the graph in Figure 3.

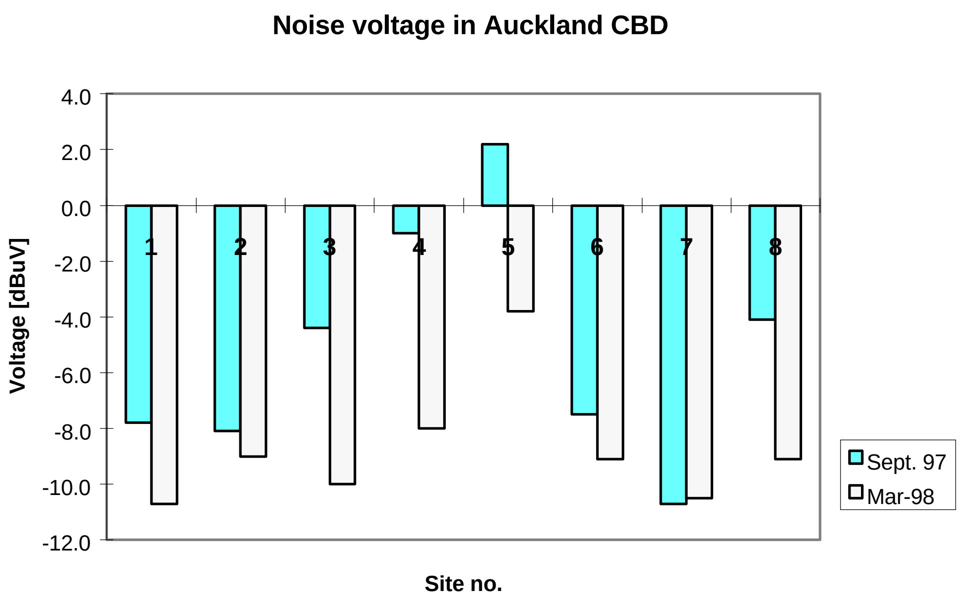

Figure 3 *Average noise voltage measured at 8 sites in Auckland CBD before and during the power cuts. Receiver IF bandwidth was 10 kHz, measurement time 500 ms*

We consider that an ongoing noise floor measurement programme is required to confirm these results, compare them with other areas and monitor their trends over time.

6. MEASUREMENT PROGRAMME REQUIREMENTS

6.1. Receivers

Based on the Auckland trial measurements it is recommended that a noise measuring receiver be used for long term monitoring. Ideally it should be automated so that measurements can be made at any time of the day and any day of the week. Automation is also necessary if more than one type of detector is to be used, to minimise the potential of human error.

Possible equipment alternatives are:

1 A Test Receiver with frequency range 20 MHz to 2050 MHz, extendable to 9 kHz and 2750 MHz; peak, average, rms detectors. Programmable, with disk drive for data storage, six pre-set IF bandwidths, automatic attenuation setting and IF panoramic display

This is the most comprehensive option. It would give us the opportunity to fully automate our measurements and obtain the data on disk. With its IF panoramic display it can work as a spectrum analyser and would enable us to first scan the spectrum to find unoccupied parts in which to measure. Scanning would be useful in identifying any unexpected interference which may arise from nearby adjacent channels or transmitter harmonics.

It would also reduce set-up and measurement time, i.e. enable us to obtain the most data points in the shortest time. Three detector types would allow the most useful results to be obtained. It is the most expensive option, though.

2 A Test Receiver with frequency Range 20 MHz to 1 GHz, peak, average, rms detectors. Programmable, has disk drive for data storage, six pre-set IF bandwidths and automatic attenuation setting.

A very good receiver, for the lower price and a bit more basic than the first one. Does not have the IF display nor the tracking generator and covers a narrower frequency range. Possible to be fully automated, and the data stored on disk.

3 An EMI Test Receiver, frequency Range 9 kHz to 2.75 GHz, peak, average, quasi peak detectors. Programmable, disk drive for data storage, three pre-set IF bandwidths and IF panoramic display

Good value for money. Does not have the IF display nor the rms detector, has fewer IF bandwidths than options 1 or 2, but covers a wide range of frequencies, from MF to microwave. Has the IF display and disk drive and is possible to be automated.

All of the above three receivers can take measurements with all detectors simultaneously, thus significantly reducing measurement time.

4 Repairing the existing Measuring Receiver**,** currently not operational. Frequency range 20 to 1300 MHz, has peak and average detectors, four pre-set IF bandwidths

A compromise, at reasonable cost. The receiver would require servicing and re-calibration, which may require it to be returned to the factory. It is capable of being interfaced with a PC for automation and data recording, but an investigation into suitable software would be required, though it shouldn't pose a problem. It is not capable of measuring in the MF band, does not have the IF display or the rms detector. It covers a narrower frequency range than other options.

This option would require purchase of a PC (laptop) for automation and control. It is still preferred that a compact, lighter and automatable receiver be procured in the long term.

All of the above mentioned receivers have in-built preamplifiers and the same sensitivity of around -20 dBμV in 10 kHz IF bandwidth.

5 A number of other options were considered, but rejected, among which**:**

a) The option of using fixed tuned landmobile (L/M) receivers, which was rejected due to the following reasons:

This would require the purchase of a number of fixed tuned landmobile receivers, one for each of the frequencies (or frequency bands) to be monitored.

The transfer method of measurement would have to be used, which requires the level of the signal from a signal generator to be noted with and without an antenna connected to the receiver to achieve a selected SINAD.

The disadvantages of this method include:

- Not able to be automated
- No means of recording data, other than by hand
- Not possible to measure in wider bandwidths
- More chance of human error, much higher labour costs
- Immeasurably more time consuming
- Technology dependent. Land mobile receivers, unless from the same manufacturer, would behave differently and cause inconsistency in measurements. However, choosing one manufacturer for consistency reasons might attract critique from others. Also, some L/M receivers have noise cancelling circuitry which is not desirable for noise measuring.
- FM discriminator characteristics of some receivers might distort measurement results. Audio stage distortion is another danger.
- A dedicated test instrument for conducting SINAD measurements would be required, such as HP8920A – adding significant costs to the project – which nullifies the basic idea of saving on equipment
  If we were to use the existing test instruments, they must all be calibrated to the same standard and available when required. District offices usually use them extensively and require them to be available at short notice.
- Difficult to convert measurements to field strengths or other meaningful units.
- Would require constant presence at a site, for all the duration of the measurements
- The labour costs would depend on the number, duration and time of the day and days of the week involved. It would not be possible to obtain data for different times of the day, especially evening or night, and this data is important in residential areas.

b) Combined Spectrum Analyser / EMI receiver (other brand). It is a quality laboratory bench-test type instrument, fairly sensitive, incorporating a pre-amplifier, with excellent spectrum display features. It is not ideally suited for noise floor measurements for the following reasons:

- Physically large and heavy, not portable
- A spectrum analyser by nature, not operating in receiver mode by default
- Requires experienced user, familiar with spectrum analyser features. Not suitable for manual operation by field staff
- Requires knowledge of CISPR16 to identify what IF filter shape factors are in use at any time
- Measurements are made by positioning a small marker across a panorama display, which requires placement for every sweep taken if absolute peak per measurement interval is to be measured
- more expensive than other options.

c) EMI Receiver, frequency range 150 kHz to 2.5 GHz, has peak, average, quasi peak detectors and three pre-set IF bandwidths

Even though it is very reasonably priced and covers a wide range of frequencies, this option was rejected because the receiver does not have the built-in preamplifier nor the disk drive. To achieve the necessary sensitivity it would require an external preamplifier with a cumbersome control procedure; and in order to fully automate (i.e. program) measurements the way we require and store data, an external PC would be needed. This compromises the idea of a simple, compact and portable set-up, and increases the hardware and labour cost. It does not have the IF display nor the rms detector.

6.2. Antennas

For VHF/UHF:

Coaxial Dipole

- Vertically polarised
- Compact and portable
- Broadband, omnidirectional - one can cover a wide frequency range
- 80 - 1300 MHz
- Sturdy design, weather resistant, minimal wind load

AND

Biconical antenna

- Broadband, 20 - 300 MHz
- Physically large
- Reduced sensitivity around 20 MHz.

Connecting only two antennas would have advantages in being able to use a 6 dB power splitter which is simple and requires no switching. The loss of 6 dB could be compensated for by good receiver sensitivity.

Active antennas
were considered, but rejected because of their susceptibility to overloading by strong signals. A very good sensitivity that they have may be replaced by a good receiver sensitivity.

OR

Dipoles tuned to the appropriate frequency or band

- Would require one antenna for each frequency
- Recommend one set of antennas moved from site to site for consistency of results
- Requires common mounting system at all sites
- May be difficult to mount several antennas at some sites
- Requires separate mountings for horizontal and vertical polarisation
- Some form of switching between antennas required if to be automated

Alternatively a **discone** type antenna could be considered:

- Good VSWR over a wide range of frequencies
- Low gain
- More difficult to transport and assemble

For MF/HF:

Active antenna is the best solution:

- Active Rod Antenna
- Frequency range 50 kHz - 30 MHz

Could use existing **Zespol** loops held in district offices and seldom used

- Only suitable for manual operation
- Directional, restricted in bandwidth
- Prone to overloading from strong signals
- Have high K factor and poor conversion
- Not weatherproof

Alternatives may be **tuned vertical whips** or **long wire dipoles**, which may be problematic, as well. Precisely determining the K factor of a dipole is very difficult. Tuned verticals may be more practical from that point of view, but transport could be difficult.

For MF/HF measurements, a receiver that is capable of measuring down to at least 150 kHz would be required. Alternatively, existing F/S receiver (in the Ministry Field Offices) could be used. It is portable, measures 500 kHz – 5 MHz, but is totally manual and directional and has a cumbersome calibration procedure.

Generally, with any option chosen, the Ministry would have greater benefits than just noise measurements. The equipment purchased, when not used for the project, can be used for other measurements or testing, especially where good quality equipment is required.

6.3. Measurement Sites and Frequencies

- Long term access required, say five years or more
- Able to erect antennas for measurement duration
- 230 volt mains power required
- Weatherproof shelter
- A number of different environments **i.e.** commercial, residential and industrial in different centres required
- Furthermore, a very quiet reference site where little change in noise floor levels is expected would be ideal
- Auckland area measurement essential because of the high use of the spectrum and the large amount of interference sources
- Measurements at landmobile and broadcasting transmitter sites would be ideal, but this may require the use of the filters to prevent intermodulation problems in the measuring receivers

A number of respondents to our industry survey offered access to their sites. Some of them will be approached once the equipment is procured.

Frequencies for conducting long term measurements will be the unoccupied frequencies – if possible common throughout New Zealand. The view expressed in the industry is that the Ministry should set aside some control frequencies for noise monitoring – from those that are currently not in use.

6.4. Measurement Bandwidths, Polarisation and Time

Like in the trial, measurements would be conducted using the IF bandwidths of 10 kHz and 120 kHz, taking average and peak readings – and if the equipment allows, rms. The noise values in the bandwidths in between will be extrapolated. (In the case of purchasing a new receiver as in the options 1 or 2, it would be possible to make measurements in more bandwidths – 15 or 250 kHz). The trial has shown a great degree of linearity in that frequency range, which also agrees with the data in literature. That is, increasing the IF b/w from 10 kHz to 120 kHz the average noise F/S increased by the factor 10 log 120/10 = 10.8 dB. Only for much wider bandwidths (e.g. for spread spectrum applications), experimental data (from literature) shows departure from linearity and this data can be provided to any party interested in setting up a wideband service.

In general, average noise field strengths (in μV/m) are linearly dependent on receiver bandwidth, and peak values increase substantially as the receiver bandwidth is increased.

NFT is planning to measure both vertically and horizontally polarised signals. However, depending on the antennas available, we regard vertical polarisation as more common, so the first set of antennas purchased may be for vertical polarisation, with easy adding of horizontal polarisation later.

Most appropriate measurement time is 500 ms, as in a trial. It is sufficient to show peak values, yet short enough to enable collection of many data points in a reasonable time.

6.5. Software

For recording of results at measurement site and forming a database, some software for data processing is required. For the beginning, however, simple spreadsheets would be sufficient. Ideal results would be a table of levels at specific times on the frequencies of interest, e.g:

Time **Freq.**	*00:00*	*01:00*	*02:00*	*03:00*	*04:00*	*05:00*	*06:00*	…
f1								
f2								
f3								
f4								
…								

A table like this can be filled for every site and every day of monitoring.

Over time, a database would be formed, containing all the measurement data and enabling statistical analyses of various kinds (e.g. short-term variation, daily, weekly or monthly changes, etc.).

Some controlling software would also be required for antenna switching, if more than one or two antennas are to be used.

7. RECOMMENDATIONS

The trial measurements conducted in Auckland show that electromagnetic noise floor levels may already be high enough to affect existing radio services.

In order to confirm this and to determine if the levels are increasing with time it will be necessary to set up a monitoring programme. Its output may serve as input and feedback for other standards and regulatory bodies, such as EMC.

We recommend that the long term monitoring programme commence, using one of the options available for equipment, preferably fully automated.

If automation is not initially possible, measurements could be made manually using any of the equipment. This would restrict the number and times of measurements made.

AND

Purchase a set of antennas to cover all the frequency bands of interest.

8. ACKNOWLEDGEMENTS

The Noise Floor Team would like to thank all the industry representatives who took part in our survey. Thanks to everybody at the Ministry Head office and Field offices who offered us help and advice, and to all the CTO's who allowed their staff to participate in the team's activities. Thanks to Chris Underwood who helped us with presentation of this booklet. The NFT wishes to express special thanks to Kevin Everitt, whose expertise in instruments and measurement techniques was invaluable.

9. APPENDICES

Attached are the following appendices:

Appendix 1 **Survey questionnaire**

Appendix 2 **Questionnaire results**

Appendix 3 **Engineering report on trial measurements, August 1997**

Appendix 4 **Table of new measurement results, March 1998**

Appendix 1

Industry Survey Questionnaire

COMMERCE

MINISTRY OF COMMERCE

Te Manatū Tauhokohoko

COMMUNICATIONS DIVISION

Radio Frequency Noise Floor Measurement Project

Information Assessment Survey

Introduction

There has been a perception by many people in the radio industry that Radio Spectrum noise floor levels have been rising with time. In order to ascertain whether in fact the RF noise floor levels are rising or raised noise floors are becoming more widespread, the Communication Division is proposing to undertake a long term study and measurement programme.

Aim

To set up a programme to obtain information on the levels and sources of man made noise and its variation over time, as it affects radiocommunications.

Purpose

The purpose of this survey is to obtain information on other persons' or organisations' experience of rising RF noise floors and whether they consider it to be a problem now, or expect it to be in the future.

Who Can Answer

If you think that there is someone in your organisation who may also have an interest in completing this questionnaire please feel free to pass on a blank copy.

How to Answer

Please complete the attached questionnaire and return it by 31 January 1997 in the envelope provided. Feel free to add any information you think may be relevant to this project.

Dissemination of Information

In order that the report resulting from this study is of the maximum practical value, it is essential that the summarised results of this survey be included (probably as an appendix to the report). It is therefore necessary that you identify any information which you would wish to be withheld from release to other parties under the commercial confidentiality provisions of the Official Information Act. It is, of course, hoped that any such restrictions will be the absolute minimum, so that the report can be as complete as possible.

Contact Names

If you need more information regarding this questionnaire, you may contact:

Alexandra Preskar-Manich	– Engineering Services, Head Office, Wellington, Ph (04) 472 0030 ext 8291
Paul Paterson	– Palmerston North District Office, Ph (06) 356 6710
Chris Brennan	– Tauranga District Office, Ph (07) 577 9229
Tan Huynh	– Auckland Laboratory, Ph (09) 360 0862

NOISE FLOOR LEVEL MEASUREMENT
PROJECT QUESTIONNAIRE

1 Are you in any way concerned that the level of radio spectrum noise floor might be rising:

☐ Yes
☐ No

If yes, please go to question 2.
If no, you may wish to stop at this point and return the questionnaire. We would, however, still welcome any additional contribution you could make by answering any additional questions.

2 Do you think that man made RF noise floor levels will with time:

☐ Increase
☐ Remain the same
☐ Decrease
☐ Uncertain

3 Do you see the need for a project to plot the levels of any rising radio spectrum noise floor as:

☐ Most important
☐ Important
☐ Not important

4 What part(s) of the radio spectrum do you see as being most susceptible to a rising noise floor level of importance:

☐ Below 30MHz
☐ 30-300MHz
☐ 300-1000MHz
☐ Above 1000MHz
☐ All susceptible
☐ Uncertain

5 What services do you see as being most susceptible to rising noise floor levels:

☐ Fixed Radio Services
☐ Aeronautical Radio Services
☐ Landmobile Radio Services
☐ Maritime Radio Services
☐ Sound Broadcasting Services
☐ Television Broadcasting Services
☐ Analogue Radio Services
☐ Digital Radio Services
☐ Uncertain
☐ Others (please detail)

____

____

6 What locations do you think are most likely to be prone to experiencing high noise floors:

- ☐ Industrial Areas
- ☐ Inner City Commercial Areas
- ☐ Residential areas
- ☐ Rural Areas
- ☐ Hill Top Radio Sites (low power)
- ☐ Hill Top Radio Sites (high power)
- ☐ Uncertain

7 What effect do you expect that rising noise floor levels will have on the radio services you have indicated:

____

____

____

____

____

8 What types of equipment or equipment characteristics do you think may be contributing to rising noise floor levels or their effect:

- ☐ Information Technology Equipment
- ☐ Domestic Appliances
- ☐ Broadcasting Transmitters
- ☐ Landmobile/Cellular Transmitters
- ☐ Restricted Radiation Devices
- ☐ Increased Receiver Sensitivity
- ☐ Uncertain
- ☐ Other (please detail)

____

____

9 Do you have any examples of problems of high radio noise floor levels you have experienced and the sources of noise if identified:

____

____

____

____

____

10 Do you think that noise floor levels are influenced by:

- ☐ Poor equipment compliance with the relevant specifications?
- ☐ Equipment specification allowable limits being set too high?
- ☐ Inadequate site co-ordination?
- ☐ Uncertain

11 What information do you think should be collected by any noise level monitoring programme:

____

____

____

____

____

12 What methods do you think should be used to collect and present the information:

____

____

____

____

____

13 Do you know of any other existing or planned programme to collect noise floor level information:

- ☐ No
- ☐ Yes (please detail)

____

____

____

____

____

14 Do you know of any other person or organisation who may be able to provide useful information by completing this questionnaire:

☐ No
☐ Yes (please detail)

____

____

____

____

____

15 Do you wish to contribute to the project in any other way eg provision of access to monitoring sites:

☐ No
☐ Yes (please detail)

____

____

____

____

____

Should we wish to follow up your answers you may wish to supply the following:

Your Name: ____

Address: ____

Contact Phone Number: ____

Appendix 2

Questionnaire Results

Ministry of Commerce, Communications Division
P.O.Box 2847, Wellington, New Zealand

February-March 1997

NOISE FLOOR SURVEY OUTCOME

Electromagnetic Noise and its Effects

EXECUTIVE SUMMARY

During the last few months of 1996 a survey was carried out in the industry, re electromagnetic noise and effects of the increased electromagnetic emissions from different sources. The results are now summarised and presented in this report. They reflect both the general concerns of the users and specific users' interests.

95% of the replies received showed that the respondents were concerned that the RF noise floor was rising. Landmobile and fixed radio services were perceived to be the most likely to be affected.

The replies suggest that any measurement programme should be conducted over a wide range of frequencies and a variety of areas, particularly industrial, commercial and hill top radio sites.

The results also indicate that there is some concern that there should be more checks to ensure that radio transmitters, information technology equipment and other interfering equipment complies with licence and specification conditions.

RECOMMENDATION

That a long term monitoring programme of RF noise floor at selected locations be commenced.

SUMMARY OF THE RESULTS

Number of questionnaires sent:	around 200
Number of replies received:	73

Some of the questions have not been answered, some of the questions have more than one answer. That is why the number of individual replies (added up) differs from the total number of replies.

Question number			*No. of answers*
1	**Are you in any way concerned that the level of radio spectrum noise floor might be rising:**		
	☐	Yes	68
	☐	No	4
2	**Do you think that man made RF noise floor levels will with time:**		
	☐	Increase	70
	☐	Remain the same	0
	☐	Decrease	0
	☐	Uncertain	3
3	**Do you see the need for a project to plot the levels of any rising radio spectrum noise floor as:**		
	☐	Most important	24
	☐	Important	46
	☐	Not important	5
4	**What part(s) of the radio spectrum do you see as being most susceptible to a rising noise floor level of importance:**		
	☐	Below 30MHz	26
	☐	30-300MHz	41
	☐	300-1000MHz	22
	☐	Above 1000MHz	2
	☐	All susceptible	20
	☐	Uncertain	5
5	**What services do you see as being most susceptible to rising noise floor levels:**		
	☐	Fixed Radio Services	39
	☐	Aeronautical Radio Services	21
	☐	Landmobile Radio Services	53
	☐	Maritime Radio Services	21
	☐	Sound Broadcasting Services	17
	☐	Television Broadcasting Services	17
	☐	Analogue Radio Services	31
	☐	Digital Radio Services	17
	☐	Uncertain	6
	☐	Others (please detail)	9 (Amateur)

6 What locations do you think are most likely to be prone to experiencing high noise floors:

☐	Industrial Areas	55
☐	Inner City Commercial Areas	60
☐	Residential areas	21
☐	Rural Areas	2
☐	Hill Top Radio Sites (low power)	19
☐	Hill Top Radio Sites (high power)	33
☐	Uncertain	2

7 What effect do you expect that rising noise floor levels will have on the radio services you have indicated?

As the majority of questionnaires returned were from landmobile and fixed service users, the replies reflected their concerns. The range of concerns are covered by the following typical comments:

- Loss of coverage or reduced ranges
- Shorter path lengths
- Decreased signal to noise ratios
- Data loss or lower data transfer rates
- Loss of fade margin
- Need for higher transmitter powers and antenna gains
- Additional transmitter sites required to compensate for loss of coverage
- Acceptance of lower quality signals required
- Station or network redesigns required and associated costs
- Pressure on available radio spectrum because of noise affecting frequencies or bands and additional assignments being required to provide for new transmitter sites
- Mobiles (trunk and cellular) locking onto weak signals because stronger signals masked by noise
- Increased time and effort required to trace and eliminate problems
- Requirement to locate HF receivers in quiet areas and operate by remote control
- Increased interference to domestic broadcast services

8 What types of equipment or equipment characteristics do you think may be contributing to rising noise floor levels or their effect:

☐	Information Technology Equipment	60
☐	Domestic Appliances	33
☐	Broadcasting Transmitters	40
☐	Landmobile/Cellular Transmitters	24
☐	Restricted Radiation Devices	17
☐	Increased Receiver Sensitivity	13
☐	Uncertain	1
☐	Other (please detail)	19

9 Do you have any examples of problems of high radio noise floor levels you have experienced and the sources of noise if identified:

Some users noted the problems they are having.

10 Do you think that noise floor levels are influenced by:

☐	Poor equipment compliance with the relevant specifications?	42
☐	Equipment specification allowable limits being set too high?	33
☐	Inadequate site co-ordination?	39
☐	Uncertain	11

11 What information do you think should be collected by any noise level monitoring programme?

Apart from the expected answers on recording noise levels, times etc there were a surprising number of calls to collect information on the sources of noise and to ensure that apparatus complied with the required technical standards

Typical comments were:

- Measure noise floor levels at various locations, frequencies, times and from different sources
- Measure noise levels at various locations including a quiet site
- Measure noise trends with time
- Measure averages over 24 hours and 7 days
- Measure constant and intermittent noise levels
- Measure in band noise levels over several days
- Investigate over wide range of frequencies 1MHz - 3GHz
- Identify location of high noise areas
- Identify sources of noise
- Peak and average levels should be recorded
- Use peak hold and vary bandwidths
- Measure Quasi peak levels
- Use fixed and mobile antennas
- Measure the effect of ionosphere depletion on noise levels
- Measure relationship between noise and licence parameters
- Make SINAD measurements
- Measure noise levels and frequencies of ITE and other man-made equipment
- As ITE equipment speeds increase so is range of frequencies affected
- Record changes in noise floors (at a site) with installation of new or replacement equipment
- Measure bandwidth of transmissions (for compliance)
- Measure excessive bandwidth’s and spurious emissions which may affect other receivers
- Check telepaging & FM transmitters (for compliance)
- Check spectral purity of transmitters and other apparatus
- In the allocation of FM broadcast frequencies and power give consideration to the effects on other users
- Take account of affects of zoning, **ie** placing transmitters near residential areas
- Record methods of eliminating noise sources
- Measure and record power of transmitters
- Record gain of antennas
- Have a data base of site parameters, **eg** transmitter powers, HRP’s, placement of towers etc
- Record the affects of RF on ITE equipment

12

What methods do you think should be used to collect the information?

Most answers were related to the respondent's specific interest/s, and covered matters ranging from where measurements should be made, through techniques, measuring apparatus, frequencies of interest, to the duration and funding of the tests.

Test site suggestions:

- Sites with problems.
- Sites selected to provide a range of expected noise levels, ranging from multi-use broadcasting through urban and rural to low-noise "control" sites.
- Inside office buildings, homes, shops.

Frequencies:

- Affected frequencies
- Selected frequencies
- Range of frequencies

Equipment:

- Spectrum analyser
- Low noise receiver with specifications at least as good as affected receivers
- Quasi-peak detection for burst noise measurements, average detection for longer period noise
- Antennae for specific affected frequencies
- Antenna in proximity to affected services
- Antenna remote (100m - 500m) from service under measurement
- Measure directly at TX output

Technique:

- In accordance with FCC Part 14
- Use NZS 6609.2 (1990)
- Refer to DSE Report 156, No 1309, ISN 0112-7683

When:

- Continuously (permanently installed noise monitors at selected sites)
- Six-monthly
- Annually
- Initially and whenever changes made at a site

Miscellaneous:

- Collection of data to be done or monitored by Ministry of Commerce (Radio Operations) staff
- Costs to be funded by Government

What methods do you think should be used to present the information?

The favoured method was for graphical presentation of the results, with a variety of suggestions as to how these should be made available.

- Graphically - levels averaged for environment, against frequency
- Graphically - for frequencies between 0.5F and 5F (where F= frequency of interest), for signals above -78dBm
- Numerically - showing before and after levels following new installations or changes at a site
- As a ratio in dBW/m^2, in 1,4 or 16kHz bandwidth up to 1GHz, and 1MHz bandwidth above 1GHz
- Projections should be made, predicting future noise levels
- Results should be made available to industry
- Results should be published through the news media, through magazines such as Radio Spectrum Management, and made available on the Internet

13 Do you know of any other existing or planned programme to collect noise floor level information?

Only two respondents made suggestions about possibly relevant studies. Neither suggestion was in fact relevant to the planned project.

14 Do you know of any other person or organisation who may be able to provide useful information by completing this questionnaire:

Very few suggestions were made.

15 Do you wish to contribute to the project in any other way eg provision of access to monitoring sites:

A number of respondents offered access to the sites they own.
Some offered help with data collection and/or presentation.

For the EM Noise Monitoring Team

Alexandra Preskar-Manich
Assistant Engineer

Appendix 3

Engineering Report on Trial Measurements

Report on Noise Floor Trial Measurements

Conducted in Auckland
28 & 29 August 1997

SEPTEMBER 1997

Ministry of Commerce, Communications Division
P.O.Box 2847, Wellington, New Zealand

ENGINEERING REPORT ON NOISE FLOOR FIELD MEASUREMENTS CONDUCTED IN AUCKLAND ON 28 & 29 AUGUST 1997

1. Introduction

The noise floor team and Kevin Everitt met on 28 August 1997 at the Auckland Laboratory. The team members recapped all the main points and conclusions from the previous meetings. Proposed methods of making measurements were discussed again, particularly "transfer method" and direct measurements. It was decided that with the equipment available we could carry out transfer method in only one frequency band (landmobile, 150 MHz), but that would be sufficient to see its practical value.

IF receiver bandwidth was also discussed and it was decided that the most useful results would be obtained if all the measurements were done in the same bandwidth. Option of different bandwidths in different frequency bands – reflecting different services currently in operation – was also discussed. However, it was concluded that the results should be "objective", meaning given in constant bandwidth, and for any future usage of the spectrum, noise in the desired bandwidth can be easily calculated. The parameter to be determined with the trial is *how wide* that constant measurement bandwidth should be.

The equipment to be used was as follows:

Rhode & Schwarz ESVS receiver
Takeda Riken TR1722 dipole antenna
Hamilton District van and telescopic mast
Hewlett Packard 8920A test set
Directional coupler
Philips PRM80V landmobile receiver

1.1. Overture to measurements

The frequencies 28.5 MHz, 72 MHz, 150 MHz and 250.5 MHz were identified as unallocated and at the same time reasonably spread over the spectrum of interest. It was decided that unless measurements show a presence of a signal there, those frequencies would be suitable for measurements.

The initial preparations included checking the sensitivity of the ESVS receiver: it was checked with a signal generator connected to the input terminals and it was noted that signals to approximately -127 dBm could be measured. That was constant throughout the proposed frequency range.

It was decided to try measurements at typical industrial, commercial and residential areas, as well as a quiet site. Four sites were selected:

Site one
Was at Penrose in an industrial area, under 220 kV power lines and near some 11 kV power lines.

Site two
Was a residential area also in Penrose. These measurements were conducted off the street in a church car park.

Site three
Was Lloyd Elsmore Park in Papakura, which was chosen as being a relatively quiet area.

Site four
Was the Auckland Radio Operations District Office car park which was chosen as typical city commercial area.

2. Methodology

2.1. Direct measurements using the Rohde & Schwarz ESVS receiver

The length of the Takeda Riken TR1722 dipole elements was adjusted to be resonant at each frequency measured, and the mast raised to approximately seven metres.

Horizontal polarisation was used as it was most convenient for adjusting the dipole lengths and also most likely to show lower noise levels than vertical polarisation.

The antenna was connected to the receiver input and measurements made on the four selected frequencies. For each frequency, four measurements were made using the peak and average detectors at the 10 kHz and 120 kHz IF bandwidths available. This R&S receiver does not have the RMS detector, which was also noted as a possible choice for measurements.

Measurements were made in dBμV to which the antenna correction factor at each frequency was added to give a field strength in dBμV/m.

2.2. Transfer method using Philips PRM 80V landmobile receiver

The Philips receiver, which was tuned to 148.95 MHz, was connected to the output port of the directional coupler. The directional coupler input port was terminated with a 50 Ohm load and the Hewlett Packard 8920A signal generator was connected to the -20 dB port.

The audio output of the Philips receiver was connected to the audio input of the Hewlett Packard 8920A to enable SINAD measurements to be made.

The signal generator level was adjusted to give a SINAD of 12 dB and the amplitude (8.3 dBμV) was noted.

The load was removed from the directional coupler input and the antenna, tuned to 150 MHz, was connected.

The signal generator level was readjusted to again give a 12 dB SINAD and the new amplitude noted.

The difference between the two signal generator amplitude readings represents the degradation in the receiver performance caused by the noise picked up by the antenna.

The new amplitude measured and calculated SINAD degradation are presented in Table 1.

3. Results

The results for the direct measurements at the four sites are attached as tables two to eight. Antenna K factors are given in Table 9.

As expected, the industrial and inner city commercial sites have the highest noise floor levels, going as high as -80 dBm. The industrial site lower frequency noise measurements were mainly high tension power line noise, while the noise measured at the commercial site is thought to be mainly vehicle ignition noise.

The residential and park areas were less noisy, however even the park was within about one hundred and fifty metres of busy roads. That may be the reason of relatively high noise levels measured, around -100 dBm.

Transfer method for SINAD = 12 dB Including coupler loss of 20 dB

f = 150 MHz

Site no.	**Signal generator input amplitude [dBuV]**		**K factor**	**F/S**	**SINAD Degradation**	**Effective Receiver Sensitivity**
	terminated 50 Ohm	with antenna	dB	dBuV/m	dB	dBm
1	-11.7 (-118.7 dBm)	-4 (-111 dBm)	14	10	7.7	-111
2	-11.7	-7.8 (-114.8 dBm)	14	6.2	3.9	-114.8
3	-11.7	-10.7 (-117.7 dBm)	14	3.3	1	-117.7

Table 1 Results of the transfer method

Site No. 1 meas.time 500 ms
Site name Penrose, industrial engine on

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	28	46	8	19	-79	-61	-99	-88	-1.9	26	44	6	17
72	18	40	-5	5	-89	-67	-112	-102	5.9	24	46	1	11
150	10	35	-8	2	-97	-72	-115	-105	13.2	23	48	5	15
250.5	10	34	-11	-0.8	-97	-73	-118	-108	17.9	28	52	7	17

Table 2 Measurement results for site 1

Site No. 2 meas.time 500 ms
Site name Residential, Penrose church engine on

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	25	47	-8	2.5	-82	-60	-115	-105	-1.9	23	45	-10	1
72	19	41	1.5	9	-88	-66	-106	-98	5.9	25	47	7	15
150	3	24	-12	-1.5	-104	-83	-119	-109	13.2	16	37	1	12
250.5	10	33	-12	-0.2	-97	-74	-119	-107	17.9	28	51	6	18

Table 3 Measurement results for site 2

Site No. 3 meas.time 500 ms
Site name Park engine on

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	21	43	-11.5	-1	-86	-64	-119	-108	-1.9	19	41	-13	-3
72	23	45	-15	-6.5	-84	-62	-122	-114	5.9	29	51	-9	-1
150	11	33	-19	-10	-96	-74	-126	-117	13.2	24	46	-6	3
250.5	6	28	-19	-7	-101	-79	-126	-114	17.9	24	46	-1	11

Table 4 Measurement results for site 3

Site No. 3 | meas.time 500 ms
Site name Quiet, Park | engine off

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	-1	18	-12.5	-1.3	-108	-89	-119.5	-108.3	-1.9	-3	16	-14	-3
72	-3	15	-16	-7	-110	-92	-123	-114	5.9	3	21	-10	-1
150	-8	11	-20	-11	-115	-96	-127	-118	13.2	5	24	-7	2
250.5	-3	19	-19	-7	-110	-88	-126	-114	17.9	15	37	-1	11

Table 5 Measurement results for site 3

Site No. 3 | meas.time 100 ms
Site name Quiet, Papakura | engine on
Lloyd Elsmore Park

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	19	43	-3	6	-88	-64	-110	-101	-1.9	17	41	-5	4
72	6	27	-15	-6	-101	-80	-122	-113	5.9	12	33	-9	0
150	10	30	-20	-11	-97	-77	-127	-118	13.2	23	43	-7	2
250.5	x	x	x	x	######	######	#VALUE!	######	17.9	#######	#######	######	#######

Table 6 Measurement results for site 3

Site No. 3 | meas.time 100 ms
Site name Quiet, Papakura | engine off
Lloyd Elsmore Park

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	20	40	-4	5.5	-87	-67	-111	-101.5	-1.9	18	38	-6	4
72	-4	16	-15	-6.5	-111	-91	-122	-113.5	5.9	2	22	-9	-1
150	-7	10	-20	-10	-114	-97	-127	-117	13.2	6	23	-7	3
250.5	x	x	x	x	######	######	#VALUE!	######	17.9	#######	#######	######	#######

Table 7 Measurement results for site 3

Site No. 4
Site name City - Akl field office

meas.time 500 ms
engine off

f [MHz]	measured dBuV				dBm				K factor dB	TOTAL F/S [dBuV/m]			
	peak		average		peak		average			peak		average	
	IFb/w=10	b/w=120	b/w=10	b/w=120	IFb/w=10	b/w=120	b/w=10	b/w=120		IFb/w=10	b/w=120	b/w=10	b/w=120
28.5	18	54	2.2	13	-89	-53	-105	-94	-1.9	16	52	0	11
72	22	35	10.9	14.1	-85	-72	-96	-93	5.9	28	41	17	20
150	15	30	0.5	8.8	-92	-77	-107	-98	13.2	28	43	14	22
250.5	2	26	-11	0	-105	-81	-118	-107	17.9	20	44	7	18

Table 8 Measurement results for site 4

Takeda Riken TR1711 logarithmic periodic array

f [MHz]	TR gain dB	calc.K dB	TR coax dB	K sum dB
28.5	0	-2.4	0.5	-1.9
72	0	5	0.9	5.9
150	0	11.6	1.6	13.2
250.5	0	16	1.9	17.9

Table 9 Values of the antenna K factor

4. Measurement uncertainties

4.1. Measuring vehicle

The initial measurements at sites one and two were done with the vehicle's engine running to maintain the battery charge because of the load produced by the measuring instruments.

As it became apparent that the vehicle ignition was affecting the measurement results at site three, measurements were made with the engine on and off to confirm our suspicions.

It was noted that the peak levels measured dropped by up to 25 dB with the engine off. All subsequent measurements were conducted with the engine off.

The motor generator used to obtain 230 V for the instruments may also be a source of noise, but this could not be confirmed as no alternative source of power was available.

4.2. Measurement time

It was noted that with the ESVS receiver, increasing the measurement time from 100 to 500 milliseconds caused an increase in the noise level measured. Care needed to be taken to ensure that the measurement time was set to 500 milliseconds when first turning on the receiver at each site. 500 milliseconds should be the measurement time for future measurements.

4.3. Philips PRM 80V receiver

For the transfer method, the IF bandwidth of the Philips PRM 80V receiver is unknown. This transceiver is declared to meet the requirements of the specification RFS 25, so it was therefore assumed to have a bandwidth of 16 kHz. The input impedance to this receiver is also assumed to be 50 Ohms, though again, this is not certain.

4.4. Antenna

Further variation in the results may have been obtained by also using vertical polarisation and varying the height of the antenna. Due to time and weather constraints this was not done.

5. Conclusions

With the Rohde & Schwarz ESVS receiver the noise floor was able to be measured at various locations. The results indicate that industrial and commercial areas have a higher noise floor than residential areas.

It appears that peak readings provide a more useful result than average readings because it is suspected that much of the noise is of an impulse nature. Average readings are still higher in industrial and commercial areas than in residential. RMS reading would be useful.

As most user radio apparatus operating near the frequencies measured operate at relativity narrow bandwidths (10 kHz and 16 kHz) it is felt that the 10 kHz bandwidth measurements provide the most useful results. Also, re-calculation for different bandwidth would be easy, using the 10 kHz noise value.

The ESVS receiver proved to be adequate to achieve some preliminary results. The new generation Rohde & Schwarz noise measuring receivers such as the ESN or ESVN may be more suitable because:

- They have lower internal noise
- Have an additional RMS detector
- Greater range of bandwidths
- On board spectrum monitor
- Antenna K factor information can be programmed in
- Can store measurement information
- Can be programmed to measure at various frequencies and times.

The ESVN receivers have several options: ESVN 20, 30 or 40, with the same basic characteristics, and the main difference being in the frequency range to be measured. It is felt that the simplest (and cheapest) one would satisfy the requirements of the noise floor measurements.

In as far as possible, any long term measurement programme should be automated to minimise the likelihood of human error in the initial set up at a new site producing invalid results.

A single wideband antenna, such as a discone would be best suited for measurements in the VHF/UHF spectrum. Possibly, more than one antenna would be needed to cover all the frequencies to be monitored.

6. Recommendations

The Noise Floor Team recommends that the ESN or ESVN receiver and a suitable antenna (e.g. discone) be procured to enable a long term noise floor monitoring programme to commence.

7. Acknowledgements

The Noise Floor Team would like to thank Roger Fillippini and his staff at the Auckland Laboratory and the Auckland District office team for their assistance and hospitality on the 28th and 29th August 1997.

Thanks also to Brian Rickerby, Tony Brown and others on the Seventh Floor at Head Office for their assistance.

Particular thanks to Kevin Everitt from the Auckland Office for sharing his knowledge, both technical and geographical during the Auckland visit.

Appendix 4

Table of New Measurement Results

Auckland power outage EMI measurements (repeat of September test to provide a comparison).											
				Sep-97	Mar-98					AV	PK
				original	re-test	AF	co-ax	original	re-test	change	change
Location	**R11 Grid**	**f(MHz)**	**detecto**	**dBuV**	**dBuV**	**dB**	**dB**	**dBuV/m**	**dBuV/m**	**dB**	**dB**
No antenna					-12.0						
No antenna					0.0						
215 Karangahape Ro	673812	80.5	AV	-7.8	-10.7	6.1	1.0	-0.7	-3.6	-2.9	
215 Karangahape Ro	673812	80.5	PK	20.0	12.0	6.1	1.0	27.1	19.1		-8.0
215 Karangahape Ro	673812	101.5	AV	-7.5	-11.0	8.1	1.4	2.0	-1.5	-3.5	
215 Karangahape Ro	673812	101.5	PK	23.0	6.0	8.1	1.4	32.5	15.5		-17.0
421 Queen Street	675813	80.5	AV	-8.1	-9.0	6.1	1.0	-1.0	-1.9	-0.9	
421 Queen Street	675813	80.5	PK	14.0	5.0	6.1	1.0	21.1	12.1		-9.0
421 Queen Street	675813	101.5	AV	-8.4	-10.5	8.1	1.4	1.1	-1.0	-2.1	
421 Queen Street	675813	101.5	PK	12.0	13.0	8.1	1.4	21.5	22.5		1.0
305 Queen Street	676817	80.5	AV	-4.4	-10.0	6.1	1.0	2.7	-2.9	-5.6	
305 Queen Street	676817	80.5	PK	16.0	4.0	6.1	1.0	23.1	11.1		-12.0
305 Queen Street	676817	101.5	AV	-6.6	-10.8	8.1	1.4	2.9	-1.3	-4.2	
305 Queen Street	676817	101.5	PK	17.0	6.0	8.1	1.4	26.5	15.5		-11.0
265 Queen Street	677819	80.5	AV	-1.0	-8.0	6.1	1.0	6.1	-0.9	-7.0	
265 Queen Street	677819	80.5	PK	45.0	12.0	6.1	1.0	52.1	19.1		-33.0
265 Queen Street	677819	101.5	AV	-2.0	-9.4	8.1	1.4	7.5	0.1	-7.4	
265 Queen Street	677819	101.5	PK	48.0	12.0	8.1	1.4	57.5	21.5		-36.0
203 Queen Street	677822	80.5	AV	2.2	-3.8	6.1	1.0	9.3	3.3	-6.0	
203 Queen Street	677822	80.5	PK	25.0	12.0	6.1	1.0	32.1	19.1		-13.0
203 Queen Street	677822	101.5	AV	-4.0	-7.3	8.1	1.4	5.5	2.2	-3.3	
203 Queen Street	677822	101.5	PK	32.0	14.0	8.1	1.4	41.5	23.5		-18.0
18 Albert Street	677825	80.5	AV	-7.5	-9.1	6.1	1.0	-0.4	-2.0	-1.6	
18 Albert Street	677825	80.5	PK	30.0	10.0	6.1	1.0	37.1	17.1		-20.0
18 Albert Street	677825	101.5	AV	-8.5	-9.9	8.1	1.4	1.0	-0.4	-1.4	
18 Albert Street	677825	101.5	PK	20.0	4.0	8.1	1.4	29.5	13.5		-16.0
Hyatt, Princess St	683822	80.5	AV	-10.7	-10.5	6.1	1.0	-3.6	-3.4	0.2	
Hyatt, Princess St	683822	80.5	PK	11.0	4.0	6.1	1.0	18.1	11.1		-7.0
Hyatt, Princess St	683822	101.5	AV	-10.0	-10.6	8.1	1.4	-0.5	-1.1	-0.6	
Hyatt, Princess St	683822	101.5	PK	11.0	3.0	8.1	1.4	20.5	12.5		-8.0
65 Shortland Street	682824	80.5	AV	-4.1	-9.1	6.1	1.0	3.0	-2.0	-5.0	
65 Shortland Street	682824	80.5	PK	9.0	4.0	6.1	1.0	16.1	11.1		-5.0
65 Shortland Street	682824	101.5	AV	-6.7	-8.5	8.1	1.4	2.8	1.0	-1.8	
65 Shortland Street	682824	101.5	PK	18.0	9.0	8.1	1.4	27.5	18.5		-9.0
								Average reduction		-3.3	-13.8
								Greatest reduction		-7.4	-36.0
Notes:											
Pre-amplifier option ON											
Attenuator set to AUTO											
Measurement time 500ms											
Bandwidth 9 kHz (CISPR16)											
Observation for 5 minutes. Mean observed reading noted.											
Antenna at 2m agl using van mast											
Van motor off											
AV - average detector											
PK - peak detector											
11-Mar-98											