University of Southern Queensland
Faculty of Engineering and Surveying

Human Electromagnetic Radiation Exposure

A dissertation submitted by

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Abstract

The high levels of electromagnetic radiation are a concern today with such large growth in the industries of telecommunications and media broadcasting. The concerns lead to an investigation into the theory of electromagnetic radiation and an application of the theory into a practical outcome around the University of Southern Queensland. Scans were conducted around the University of Southern Queensland (USQ) campus, Toowoomba, measuring the levels of non-ionising radiation from 30MHz to 1GHz. These scans were made using a broadband antenna and a spectrum analyser.

The measurements conducted around the USQ campus underwent analysis of how each site, and signal frequency, affected the exposure within that area as well as many other characteristics of the measured signals. This was to investigate the possible methods of minimising exposure if long-term radiation risks were a concern. The conclusions of this study showed lower amplitudes of measured exposure indoors, when compared with outdoors and determining a number of sites of higher and lower exposures located around the USQ campus.

The peak values of the scans were compared to the Australian Standards, of 0.08W/kg, for general public exposure to signals from distant sources. The largest recorded experimental result was in the magnitude of 10^6 times smaller than the standard restriction. This eliminated concern for any short-term heating effects which have been discovered for levels above the Australian Standards.

The long-term effects of non-ionising electromagnetic radiation within the range of testing has not been conclusively found to have any known health risks, but also has not been able to be concluded as safe. The many studies which have been conducted discovered both positive and negative results from a number of possible effects such as cancer, behavioural changes, pregnancy difficulties, epidemiological concerns and cognitive ability to name a few.

Difficulties in research are attributed to the difficulties of finding long-term exposure incidences, or recreating these situations in controlled environments. One study which was able to determine no increased risk of cancer, or increase in the rate of rare cancers was a study of the Denmark cancer registry and mobile phone registry which was a nationwide study of over 420,000 observed cases. This study covered the largest sample size seen for a study in this field and had cancer statistics of up to 25 years mobile phone exposure.

The conclusions to this study provided people located on campus were at no risk of any short-term effects from the electromagnetic radiation exposure levels measured at USQ. The long term risks also could not be determined due to a current lack of knowledge within the scientific community but from a number of studies it appeared there was no risk of cancer developing from these signals also.

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Table of Contents

List of Figures

List of Tables

Glossary of Terms

3G	3rd Generation mobile phone network currently in place
a/c or ac	Alternating Current
ACMA	Australian Communication and Media Authority
AM	Amplitude Modulation/Modulated – Refers to either the method of modulation of a signal or in the context of radio waves the dedicated frequency range for Amplitude Modulated radio broadcasting
AMTA	Australian Mobile Telecommunications Association
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
CDMA	Code Division Multiple Access – this mobile system was in place after analogue was phased out
CT Scan	Computed Tomography – a medical scan used for body imaging
EM	Electromagnetic
EME	Electromagnetic Energy
EMF	Electromagnetic Field(s)
FM	Frequency Modulation/Modulated – Refers to either the method of modulation of a signal or in the context of radio waves the dedicated frequency range for Frequency Modulated radio broadcasting
GPS	Global Positioning System
GSM	Global System for Mobile – the system in place previous to our current 3G system
HF	High Frequency, in reference to radio wave frequency bands
Hz, kHz, MHz, GHz	Hertz, kilo-Hertz, Mega-Hertz, Giga-Hertz, Measurement Units of frequency
ICNIRP	International Commission for Non-Ionizing Radiation Protection
MRI	Magnetic Resonance Imaging – a medical scan used for body imaging
Next G	Similar to 3G mobile phone network, often referred to as 2.5G
nm	nano-metre, the standard measurement unit for electromagnetic waves
RFE	Radio Frequency Energy

RF	Radio Frequency
RMIT	Royal Melbourne Institute of Technology
SAR	Standard Absorption Rate, (Section 3.3.2.1)
UHF	Ultra High Frequency – in reference to radio wave frequency bands
USQ	University of Southern Queensland
UV	Ultraviolet Radiation
VHF	Very High Frequency, in reference to radio wave frequency bands
WHO	World Health Organisation
W/kg	Watts per kilogram, standard units for Standard Absorption Rate (SAR)

Chapter 1 - Introduction

The topic of this project is ‘Human Electromagnetic Radiation Exposure’. The topic covers all non-ionising electromagnetic radiation and the exposure risks to the general public. The topic was initiated through public concern for electromagnetic radiation and the current viewpoint today that it could be dangerous.

This concern has become more relevant with the large growth of the broadcasting and telecommunications industries. The current standards focus on limiting the electromagnetic radiation to a level which produces no short-term dangers but through research it is indistinguishable as to whether these levels carry an inherent long-term low level radiation risk.

The amount of research currently conducted around long-term low-level electromagnetic radiation is staggering and a review of these studies was conducted. The studies which were focused on were any which contained topics such as health risks, any other possible effects on living creatures, current knowledge on radiation sources or signal characteristics and measured levels of other studies similar to this one.

The experimentation, and focus on this topic, was conducted around the University of Southern Queensland campus. This area is a general public area with a large daily congregation of people and so particular focus was aimed at the public health risks and standards. Focus was aimed at areas of high risk as well as areas which were often used by the general public on a daily basis.

The largest component of investigation was the experimentation which was taken around the campus location and nearby areas. It consisted of taking signal amplitude scans at a number of locations to view the overall strengths of the many signals which the public is exposed to continuously. These consisted of FM radio, Television, Mobile phones and many private signals and to see whether there was any risk of any signals being as high as the Australian Standards.

Also analysis of the different locations and signal frequencies was conducted to view which characteristics of the signal or the location would alter the electromagnetic exposure levels. The analysis would contain statistical data analysis on the measured peak values, would require calculations into relevant data units and an analysis of the final value and the comparisons which could be made between the different locations and signals. The most important analysis was whether of not the signals that were measured were at risk of reaching the standard restrictions.

This information then allowed for conclusions to be drawn on the possible health risk that was associated with electromagnetic exposure, and when combined with the current research, determination of what the effects of such exposures could be.

Chapter 2 – Review of Theory

2.1 Electromagnetic Definition

2.1.1 Electromagnetic Waves

Electromagnetism is a very hard concept to define and one that is often taken for granted. An electromagnetic wave has no mass and propagates through space at the speed of light. It is a mystery because it has no medium to travel through, as sound does, and acts both as a waveform and a particle.

Electromagnetic waves interact with each other as waves rather than particles. So, when two electromagnetic waves occupy the same space the amplitude of the waves is summated. Two in phase waves travelling along the same route will double the amplitude, while two 180º out of phase waves travelling along the same route will eliminate each other. Today, the exact nature of electromagnetic waves still eludes researchers and research into this area continues.

Despite this fact the scientific community doesn't know its effects and how to use EM waves constructively. What is known; however, is that electromagnetic waves contain both an electric component and a magnetic component. These interact with each other; the change in one represents the amplitude of the other, and vice versa. The orientation of the magnetic component and the electric component are perpendicular to each other and directly effect the polarisation of the wave. Waves with their electric component at the same orientation are classified as polarised. An example of this is shown below in Figure 2.1.

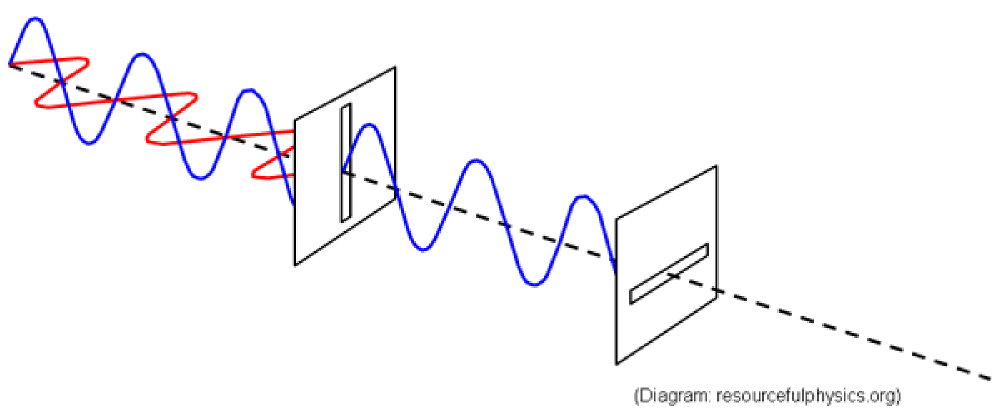

Figure 2.1: Picture of unpolarised light becoming polarised. Red and blue waves denote unpolarised light with the middle blue being polarised. (Institute of Physics, online resource)

An electromagnetic wave can be of any frequency (or wavelength) and any amplitude. Electromagnetic waves have been classified into different wavelength categories, each category with its own characteristics.

Visible light is the most commonly known electromagnetic wave category and consists of wavelengths from 380nm to 720nm, blue to red respectively. Below the 380nm wavelength is ultraviolet light, X-rays and Gamma (γ) rays. Above 720nm visible light is infrared light, microwaves and radio waves. Radio waves are characterised further into AM, FM, Long Radio waves, HF, VHF, UHF and more depending the use for that frequency of signal today.

These EM categories can be seen below in Figure 2.2.

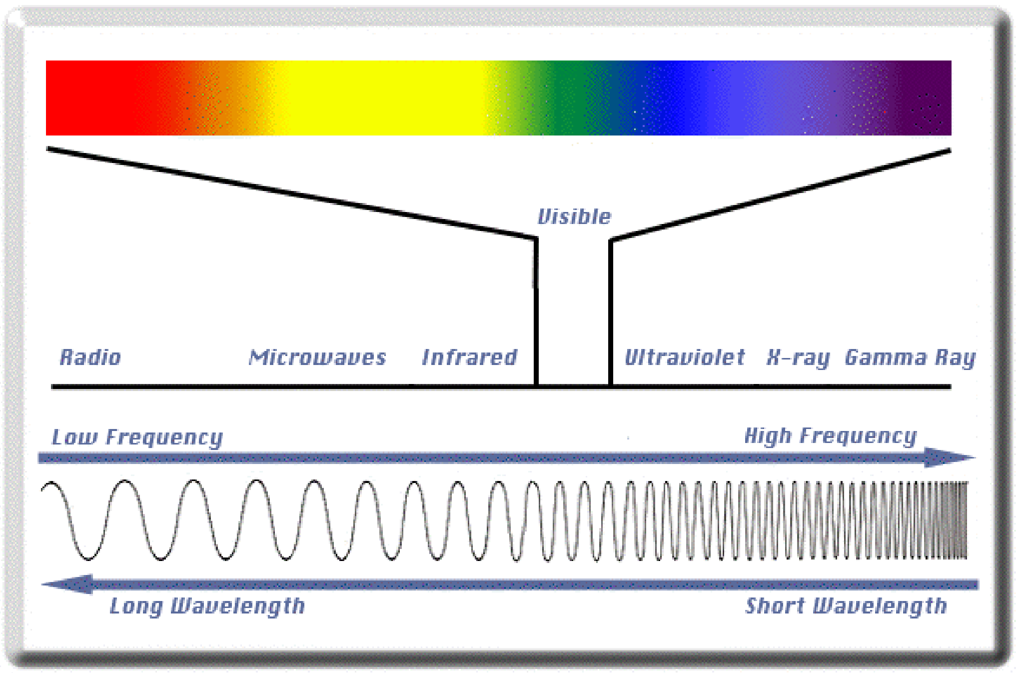

Figure 2.2: The electromagnetic spectrum. (University of Minnesota: Laboratory of Computer Science and Engineering, online resource)

2.1.2 Electromagnetic Fields/Radiation

Electromagnetic fields represent magnetic fields and electric fields. Electromagnetic fields are the three dimensional representation of electromagnetics in an area/volume. Since each electromagnetic wave has an electric and magnetic field component the representation of an area of these waves is an electromagnetic field.

A moving electric field will produce a magnetic charge and a moving magnetic field will produce an electric charge. The direct application of this can be seen from a closed circuit moving through a magnetic field. A current is produced through the circuit, dependant on the length of wire, the strength of the field and the orientation of the wire to the field. And vice versa a current moving through a wire produces a magnetic field.

Magnetic and electric fields also directly influence other fields of a similar type. An electric field will influence another electric charge or field.

This is the basis of electromagnetic radiation. Electromagnetic radiation is another term for an electromagnetic field, but is used to describe the electromagnetic field emitted from a specific object, circuit, etc. and is most often attributed to deliberate or accidental electromagnetic fields produced from man made sources.

2.2 Electromagnetic Production and Sources

2.2.1 Natural Electromagnetics

Natural Electromagnetic Radiation is the radiation which is present in our natural world, and there is no way to influence the source. There are a number of sources of natural radiation shown below.

2.2.1.1 The Sun

The Sun is the largest producer of Electromagnetic Radiation in our solar system. It provides the Earth with light and heat, as well as many unwanted electromagnetic waves such as UV, X-ray, Radio Waves and Gamma Waves.

Luckily the Earth's atmosphere filters out the majority of Gamma, X-rays and UV radiation as these are harmful to life and are classified as Ionizing Radiation. Ionizing Radiation means that the radiation has enough power (due to the high frequency when looking at light as a photon) to strip electrons from our atoms. Radiation such as gamma radiation is highly dangerous and leads to the denaturing of DNA and death of living cells and organisms, The average human being living on our planet needs to know little about this as the surface is protected by the Earth's atmosphere.

However infrared (heat), visible light, radio waves and some UV radiation all manage to reach the surface of the planet. UV radiation can have harmful effects but this will not be discussed in this dissertation. Visible light and infrared radiation are very useful to life, and without it Earth's ecosystem could not function. Radio waves are another product of the sun and these are detectable from the surface. Sun Flares and variations in the Sun's energy production can produce peaks, troughs and other variations in the radio waves emitted. The sun is a major source of radio waves but for this project's application there was no influence from it as the project looked for specific wavelength signals which were deliberately man-made.

2.2.1.2 The Earth

The Earth itself has a large scale magnetic field encompassing it. This is produced from the movements of the outer core of our planet. This outer core is made up of molten metals these metals move forming currents within the core. These movements produce the magnetic field present around Earth causing the Earth's north and south poles.

2.2.1.3 Magnets and Static

Magnets are natural sources of magnetic fields and are found in certain materials around our planet. These metals hold and retain the magnetic field and are a natural source of electromagnetic radiation for this reason.

Static electricity and lightning storms are also examples of natural electromagnetic events. These are based on the build up of an electric charge through a number of sources such as friction, ending with the release of an electric discharge, or spark.

These natural electromagnetic sources are not covered in this dissertation but are useful to know the sources for a complete theoretical background for this topic.

2.2.2 Man-Made Electromagnetics

There are two types of electromagnetic radiation produced from man-made sources. These are accidental and deliberate.

2.2.2.1 Accidental Radiation

Electromagnetic leakage is the term used for accidental radiation being produced from electronic and electrical components. Electromagnetic leakage comprises a major assessment component of this dissertation because it is present in areas of office equipment such as computers, printers, photocopiers, lighting systems, air conditioning and more.

Electromagnetic leakage is the accidental electric or magnetic field production from any circuit. The cause of EM leakage can be varied. Electrical circuit switches are often a cause of significant leakage, as well are any electrical motors. Any wire in an electronic circuit that has a current causes an electric field. The strength of this field is proportional to this current, so any high current line in a circuit can cause a large enough field to interfere with other nearby electronic circuits.

There are many other causes of leakage in electric circuits, as today there are many circuit components designed, and what these components are made of is often unknown.

Many of the components may have capacitors, inductors, switching components, as well as many other parts which may cause a leakage, and each component on its own will only cause a minor leakage.

Often these leakages can cause effects on other components, which lead to the strength increasing, and an effect elsewhere occurring. A poorly designed electronic circuit, as it gets more complex, can increase leakage to a significant amount. Also fluorescent lighting and other types of electrical equipment are also known to cause noise.

Deteriorating electronics are responsible for a large amount of EM leakage too. The most common occurrence is arcing. If a minor break in a circuits wire occurs, then arcing across this break will cause a large amount of electromagnetic noise.

Also switches, switching components and kinetic components as they were down all have an increased chance of arcing, as oxidisation occurs on contacts or formerly smooth parts get worn down and rough.

Many of these problems are only small but when combined in a large circuit they can cause significant leakage, which in effect causes significant influences on nearby electronics.

2.2.2.2 EM Leakage in this Project

While Electromagnetic Leakage is acknowledged in this project, little attention could be spared for this topic, either in calculations, or with researching theory and detection. As will be read later, scans were conducted in an office location and this was to represent a worst case scenario for EM leakage. From this the worst results could be seen and compared to results shown from other locations and situations.

2.2.2.3 About Deliberate Radiation

Deliberate Electromagnetic Radiation is any electromagnetic radiation which is produced with some sort of function in mind. While the outcome might affect areas that were unintentional or expose people which it was not intended to, it is the basis in which the signal was produced which determines if it is classified as a deliberate signal.

Some applications of deliberate signals that were not relevant to this topic are discussed below, followed by the signal production which is very relevant to this dissertation.

2.2.2.4 Instrumentation Applications

In many industries wireless instrumentation is used for measurement and control. Devices used to determine distance measurement, time, pressure, object location, object composition and more can produce an almost endless number of applications for electromagnetic radiation.

Quite often for these applications the electromagnetic wave strength is very small, only being required to propagate over very small distances for measurement purposes only. The exact use of the electromagnetics differs for each application and so cannot be classified as any single method.

2.2.2.5 Medical

Today the uses of electromagnetic radiation in medicine are ever increasing. Electromagnetic radiation is very useful in the diagnosis and treatment of many conditions.

Cancer is treated with Chemotherapy which uses high levels of radiation to destroy cancer cells. This radiation also kills healthy cells but in a controlled environment the risks to the patient can be reduced and the patient may live depending on the severity of the cancer.

Imaging devices such as MRIs, X rays, CT scans and others are used for medical diagnosis. X rays and CT scans both use x ray frequency waves to propagate through the body and be captured as an image. X ray is dangerous radiation but in smaller, controlled situations can be highly effective. MRIs use radio waves, in conjunction with large magnetic fields to produce imaging of the body.

All of these images rely on different interactions between the electromagnetic waves and the different tissue compositions of the human body to produce images of its structure.

2.2.2.6 Science and Engineering Research

Scientific and Engineering Research is obviously one area which can use electromagnetic signals and radiation.

Once again the uses of electromagnetics are so varied that it is impossible to classify all applications for this purpose. This dissertation is one example of the type of research underway but the use of EM radiation extends to many more applications. Research areas include EM use, the effects of electromagnetic radiation, using EM signals to solve the mysteries of our world, the safety of EM radiation and development of EM radiation into other useful or more efficient products.

Research is another limitless use of electromagnetic radiation and has a much broader utilisation than any other application. For example different studies may use high levels of electromagnetic radiation over long distances while others may only use minute signals. Electromagnetic radiation may be highly variable and influence objects around it or may be a static field and developing its uses into a new application.

2.2.2.7 Wireless Integration Applications

Wireless integration is just a method that can be classified as electromagnetic signal production, which is talked about in the following section. But it shall be discussed here to view the current state of advancement and development of this technology.

Today many devices are being integrated as wireless. These are not done out of necessity but instead for convenience. Around the home, devices are all becoming wireless.

Wireless networks and internet allow for computers to talk between each other as if on a wired network. Bluetooth compatibility between computers, mobile phones, keyboards and many other components are becoming the norm. Wireless keyboards, mice, headsets and speakers are all common with today's computers. Also other items such as GPS navigation gives a wireless navigation system for the car and uses satellite communication to achieve this.

2.2.3 Electromagnetic Signal Transmission

2.2.3.1 Signal Production Introduction

Electromagnetic signal production is the deliberate production and transmission of electromagnetic radiation in the form of analogue or digital signals containing information. This transmission can be from a specific site to another site, one way communication such as is often the case in industry and data logging situations. It may be single site to site communication where two matched signals are used to have two way communications. It may be one site to many broadcasting such as television or radio or could be multiple site to multiple site communication such as a taxi radio network.

There is a wide variety of uses for electromagnetic signals and is continually developing as the advancement leads to new applications for this technology, and as technology evolves.

EM signal transmission first requires specialised equipment to allow it to happen. This comes in the form of a transmitter, a receiver, or both and the key component is some sort of antenna, whether crude or advanced. Often accidental signals can be received or transmitted through items which aren't antennas but act as one through key, antenna-like characteristics but these are bad receivers and often only produce noise.

2.2.3.2 Antenna Theory

The antenna theory applies to broadcasting and telecommunications, as well as many other applications. An antenna can be anything from a single basic wire antenna to a complex antenna array.

The theory of antenna transmission is based on electromagnetic interaction between electromagnetic fields and electric current and charge difference throughout the antenna.

When a current passes through an antenna an electric field is produced around it due to the charge difference along the antenna and this field propagates outwards from the antenna. If the current is reversed, and hence reverse the charge difference, then the electric field has negative amplitude which propagates out. Depending on the antenna this is a direct relationship so a sin wave a/c current will produce a sin wave propagation signal pattern.

A simple picture of this relationship is shown below in Figure 2.3. This picture shows very simple dipole antenna and how it produces the electromagnetic signal. When applying this to more complex antennas and more complex signals the principle is still the same, but instead of a simple relationship between electric current and signal it becomes much more technical and by changing antenna shapes the signals can be redirected into more specific directions or alter its characteristics.

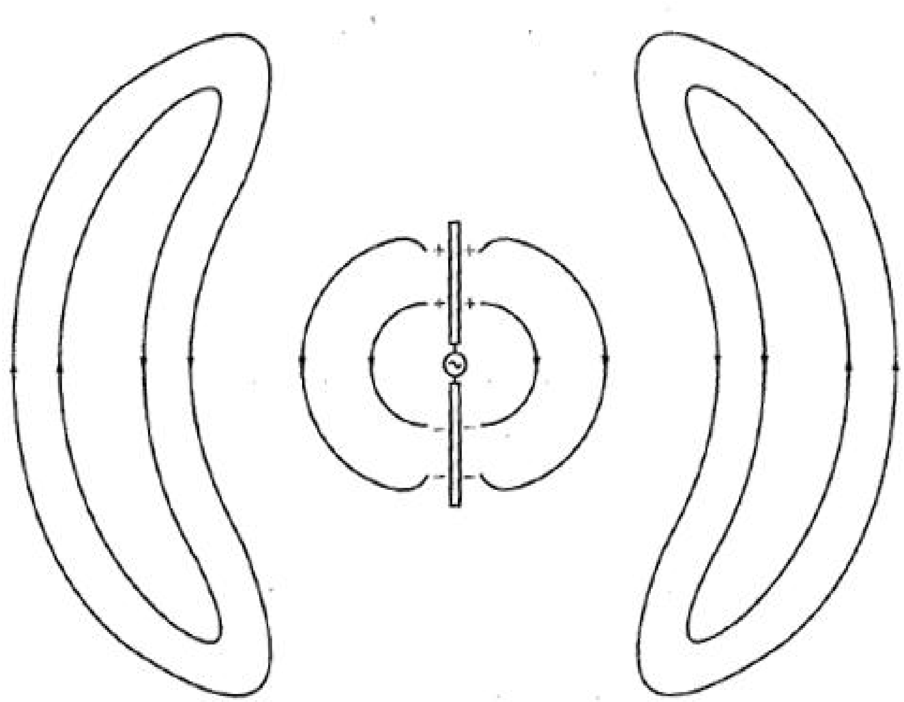

Figure 2.3: Electric Fields in the Vicinity of An Oscillating Short Dipole Antenna at the Instant When the Current is Zero and the Charge is a Maximum (Ball, 2007, p 6.5).

The main characteristic which applies to antennas is signal gain and how it applies to different directions and different frequencies.

For example shown below in Figure 2.4 is the gain characteristics over the frequency range of the antenna used for this experimentation. These can be simple graphs or may be quite complex and shows the gain or dampening effect that an antenna naturally exhibits of its frequency range.

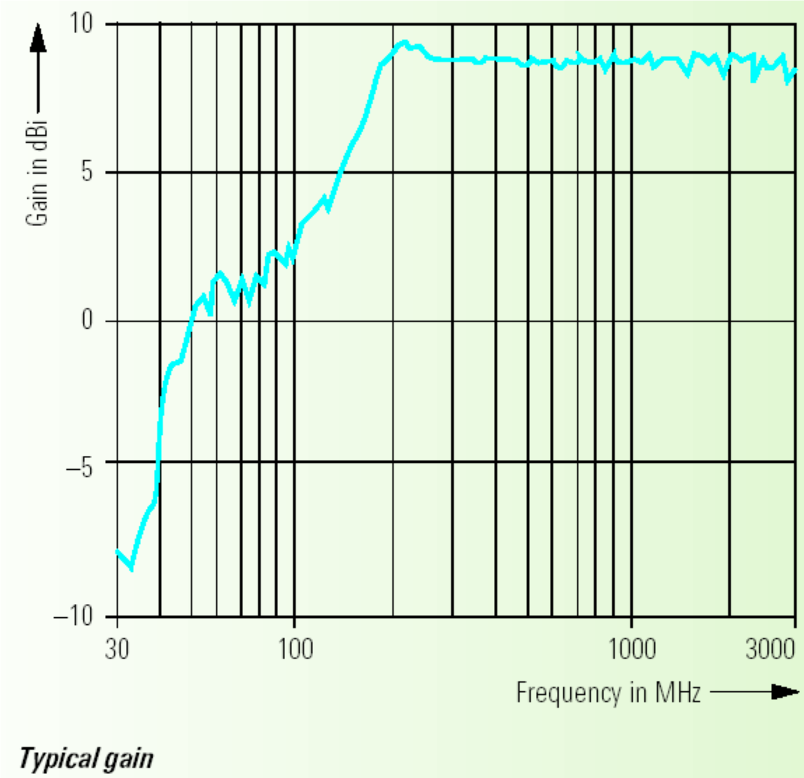

Figure 2.4: Gain characteristics from 30MHz to 3GHz for the Rohde and Schwarz HL562 Ultralog antenna. (Rohde and Schwarz, 2004, p 2)

The gain variation for the antenna to signal direction provides information on how signal detection varies according to the direction it is received from. It can be expected that nearly all antennas should have the highest gains directly ahead but it is useful to know how the peripheral angles change the signals. This allows people not to be required to know the exact direction of what is being measured.

Three examples of different gain angle tables are shown below. Two are from the Rhode and Schwarz HL562 Ultralog antenna used in this experiment, showing the 30MHz angle variation and the 3GHz angle variations. The last graph, Figure 2.6, shows just a typical, relatively simple angle graph and how they look like theoretically, rather than in real life.

It is harder to tell from the real antenna graphs but different angles exhibit gain ‘lobes’ or areas in which greater gain can be achieved. These are quite often at set angles and can be almost symmetrical in antenna theories but of course these may be vastly different than in real life.

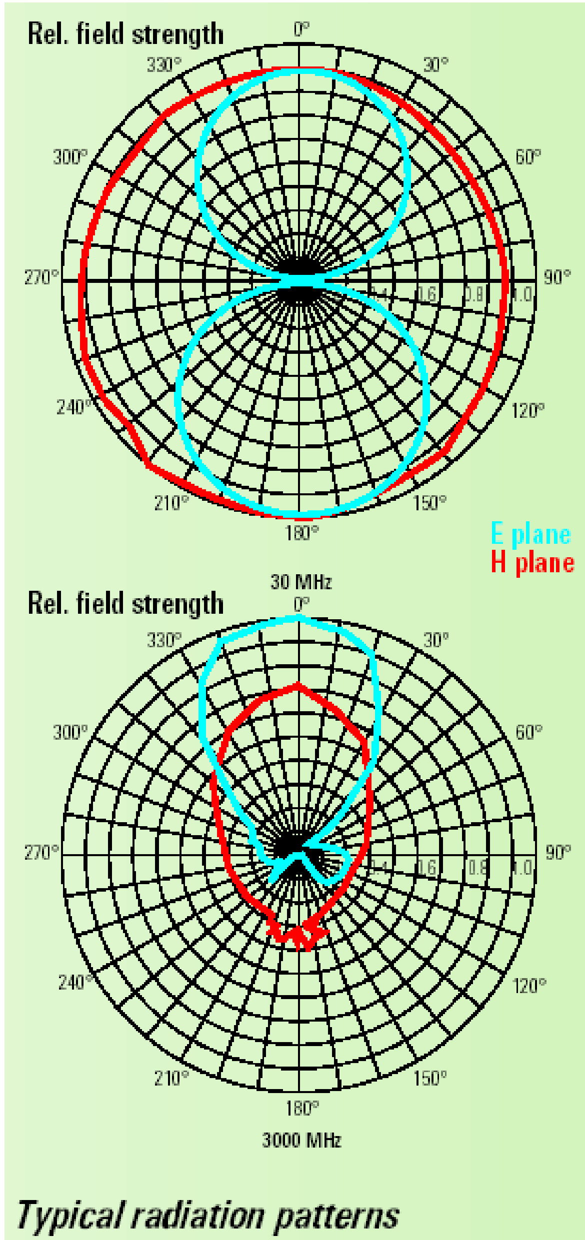

Figure 2.5: Gain characteristics for 360º rotation around the antenna for 30MHz and 3GHz for the Rhode and Schwarz HL562 Ultralog antenna. (Rohde and Schwarz, 2004, p 2)

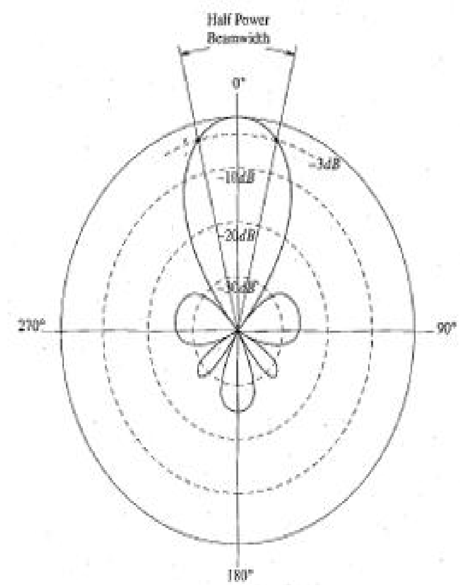

Figure 2.6: Gain characteristics for 360º rotation around the antenna for a theoretical antenna. (Ball, 2007, p 6.15)

This was a quick look into antennas and antenna theory. These days a full knowledge of antenna theory is not required. An understanding of the gains and a few characteristics which apply to the application are required and the antenna producer provides the technical background for their product.

2.2.4 Shielding and Types of Protection

As stated all electrical and electronic equipment has potential to produce radiation. Current flows, kinetic movement and magnetism are just a few accidental producers of electromagnetic radiation.

As well as this signal transmission, external interaction (measurement) and light production are a few producers of deliberate electromagnetic radiation. Whether deliberate or accidental all radiation should attempt to be shielded to reduce its influence on nearby external objects which do not require this radiation.

2.2.4.1 Minimisation Protection

Minimisation Protection is reducing accidental radiation through reducing the number, or strength of sources themselves. This includes lowering currents, as the radiation strength is directly proportional to the current strength so as current amplitude is decreased so is the radiation amplitude.

In essence this method involves minimising each part down to its most efficient size, while it is still able to safely perform its required function.

Things such as using newer, lower energy components as well as using power supplies, and parts which are not ‘overkill’ for their application.

Avoiding current loops is another means of reducing the production as a current loop amplifies the radiation produced by the current.

The advantage of minimisation is that the radiation is reduced, the efficiency of the product increases. Reducing current loops is a part of good circuit design and so should not have a major influence in a well designed circuit.

The disadvantage of this approach is that it is limited in its application and only reduces radiation, does not eliminate it. The current can only be reduced to a certain level before the electrical/electronic equipment cannot function as it is desired. Also once current loops are eliminated (or reduced to minimum feasible levels) there is little extra advantage from this approach.

2.2.4.2 Relocation Protection

Relocation of a radiation source is a very common way of reducing the strength. Overhead power lines, high broadcasting towers, hands-free mobile phone kits and fenced off transmission stations are all examples of relocation. It is moving a source away from the unwanted exposure locations. Quite often this is one of the most used ways of reducing deliberate radiation.

The advantage of relocation is that it is a very effective way of reducing high strength signals. The reduction is exponential as the distance becomes further so being 10m away from a power line is four times better than being 5m away from the same line.

This is due to 3D spherical strength reduction occurring. The formula for this is:

$$S_i = \frac{P_{rad}}{4\pi r^2}$$

S_i = Power Density of the Signal
P_{rad} = Radiated Power
r = Distance from Source

Another benefit is that quite often relocation occurs for other advantageous reasons. A tall broadcasting tower can broadcast further than a short tower so without worrying about the radiation reduction it has already been located in a position away from harming its surroundings.

Also for industrial and measurement applications public access can be removed, and safety codes be produced for its use and exposure to those who are required to work in the area.

The disadvantages of relocation are that for many applications it is not a plausible method. A mobile phone handset antenna can not be run it up a 5m tower. It is inefficient to take a small radiation-producing electronic component and move it out of a piece of electronic equipment.

As well as it being impractical in terms of design it may be found that the losses or disadvantages in such a situation outweigh the benefits. Quite often user interaction also occurs with the source of the radiation which is unavoidable.

2.2.4.3 Shielding Protection

Possibly the most common way to reduce radiation effects is shielding or screening. These are both very similar and involve the blocking of the signal by a plane of material which either absorbs, or reflects the signal. Reflective Shielding reflects the signal as it hits the barrier while Absorption shielding absorbs it in its electron structure, often retransmitting the energy in another form such as heat (low levels).

Shielding is used in a vast number of situations, many not related to this application. Nuclear shielding with lead, sun screen, sound proofing, medical equipment design are just a few other applications which involve some form of shielding.

In any broadcasting situation what is wanted is for the signal to be transmitted out to those who need to receive the signal but to limit exposure to those who don’t require receiving the signal such as nearby workers, etc.

One such example is taxi radios are automatically shielded by the roof of the taxi. For people who work at transmitting sites it may be found that work areas can be shielded to reduce the exposure to employees who are present for more than 7 hours a day. Electronic equipment such as office equipment also has in-built shielding and screening to minimise the external radiation which consumers may be exposed to during operation.

The advantage of shielding is the signal can be completely eliminated if required and shielding can be quite cheap depending on the application and level of shielding required. Due to its simplicity it is possibly the most used technique. It can also be integrated during construction and with modern machining can be added to a product very easily.

The disadvantage of shielding is the physical barrier which has to be set up. This makes connections through the shielding more difficult and may not always be appropriate. Also shielding cuts out a large range of signals and so is not selective. This may lead to signals which shouldn’t be to also be shielded. The shielding that may be wanted on the transmitter may also have an effect on a nearby receiver which is picking up different radiation.

2.2.4.4 Other Design Options

There are other design options which can alter the radiation strength that is emitted. These will be discussed shortly below.

Directional Antennas can be used when broadcasting between set points. By choosing a directional antenna it can transmit a signal with much higher amplitude in the required direction, while other unwanted directions have highly reduced amplitudes. These characteristics come from the design of the antenna itself and should be thought of with the design. A typical graph of directional amplitude is shown here in Figure 2.6 (Section 2.2.3.2, page 9).

Through using multiple smaller transmission stations to cover the same area, the maximum signal strength required is reduced. There are a number of reasons to use the mobile phone cell station setup that is currently in use and this is one advantageous reason.

If a single transmission tower only has to cover half the distance, due to signal distance reduction, it can reduce the total transmission power by four. The lower peak signal value is much safer than the higher value but two stations require much more money and complexity to set up.

2.2.4.5 Why Protect

In a lot of cases protection isn't necessary. But minimal unwanted radiation is a product of good design for all electronics and electrical equipment. As well as exposing nearby people or animals to the effects of this radiation it may also interact with other electronic equipment in unwanted ways.

For example an unwanted electrical leakage on a wire in a piece of digital electronics could result in another wire producing a digital value of one rather than zero. This could have major ramifications if it is the control system of a piece of large equipment. With modern technology these problems are far easier to fix and very little thought is required on this subject in most cases.

For some industries there are strong regulations on any electromagnetic radiation. This is especially the case in all broadcasting, mobile telecommunications and power transmission just to name a few.

These regulations are necessary for the protection of workers and the public and heavy penalties are applied to any company, or negligible person, breaking these regulations (Section 2.5, page 35).

2.2.5 Electromagnetic Radiation Today

Throughout previous sections there has been much discussion into what occurs today. Which industries use electromagnetic signals/radiation and what they are used for. There is a need to look into the condition of these industries and how the growth today has led to the current situation in which there is a public concern about electromagnetic radiation.

The largest area of growth today is easily the mobile phone telecommunications market. The level of growth in this area has been phenomenal and today almost every household has more than one mobile phone.

Table 2.1 shows the growth of mobile phone handset sales from 2002 to a predicted value for this year. Considering there is a total population in Australia of 21.5 million people and yearly mobile phone handset sales of above 9 million there is an extremely large number of handsets being sold each year.

While not all handsets are currently used it should be noted that the more that are bought, the more that are being used and so while not every handset is being used its rise in sales shows an increase in mobile phone usage. Also an increase in mobile phone handset sales and usage also leads to a need for larger support systems and larger mobile phone base stations.

Table 2.1: Annual mobile phone handset sales in Australia (Australian Mobile Telecommunications Association, 2008, online resource)

Year	Annual Mobile Phone Handset Sales (million)
2002	4.00
2003	5.98
2004	8.02
2005	8.01
2006	8.74
2007	9.28
2008 (predicted)	10.2

This growth in the mobile phone industry extends to all industries, even if the level of growth is slightly slower in other areas.

One representation of where the industry is currently is to look at electromagnetic radiation licensing. ACMA handles the licensing of all broadcasting, telecommunications, industry and other areas in which any electromagnetic signal is found. Currently 701 licences are issued for Toowoomba and surrounding areas (Australian Communications and Media Authority, 2008, online recourse). This includes licensing of the same frequency in many cases as the licence only covers certain distances before being renewed for a greater coverage.

With the number of frequency licences authorised there is also a number of site licences which are also provided. In a 20km by 20km box centred on Toowoomba there are 149 transmission sites authorised. A number of these locations can be seen below in Figure 2.7. The patch of high density sites that can be seen in the middle, towards the right side is the centre of Toowoomba.

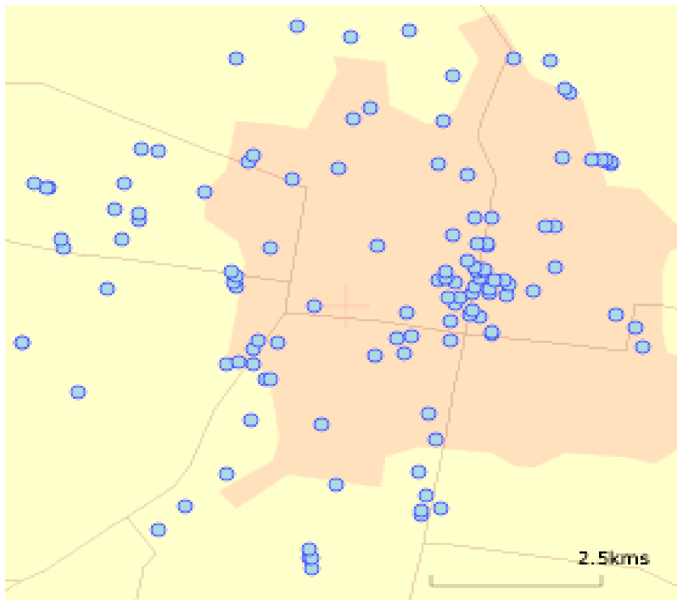

Figure 2.7: 10km x 10km view of the Toowoomba, and west Toowoomba, area showing transmission sites licensed by ACMA. (Australian Communication and Media Authority, 2008, online recourse)

2.2.6 Electromagnetic Sources for this Dissertation

There are a number of broadcasting areas of interest for this project. Because this project has a strong hold on public perception it is of great interest that a number of frequency ranges of public interest should be looked at.

As stated in (Section 3.1, page 53), discussing the equipment restrictions, only a scan range of 30MHz to 1GHz will be conducted and so this must be taken into account when considering the signal sources. The areas that were recognised are discussed below.

The frequency ranges of interest are the AM radio range, the FM radio range, the Television Broadcasting range, the mobile phone spectrum and the blue tooth spectrum, as well as possibly the 50Hz AC power range.

2.2.6.1 AM Radio Signals and AC Power

Using the 30MHz to 1GHz range it cannot be possible to measure the 50Hz AC Power Lines so this is ruled out. The AM radio broadcasting range falls from 0.5MHz to 1.1MHz and so also cannot be measured by this equipment. The AM radio broadcasting would be ideal signals to measure for, as the AM radio requires much higher initial signal strength to allow it to carry as required and is commonly very close to the standard restrictions near the site.

2.2.6.2 FM Radio Signals

The FM broadcast range falls from 87.5MHz to 108MHz and so is ideal for measurements. The number of FM radio stations able to be detected around Toowoomba is approximately 10-15 signals depending on the atmospheric conditions.

Frequency modulation, which is used for FM radio, has a quite a low overall amplitude in comparison to other modulation methods. This is because the amplitude only needs to be high enough to transmit the signal, and the signal data itself is stored as a frequency change rather than an amplitude change as can be seen in AM radio.

Additionally some developments in radio which have lead to any increase in the signal data capacity making the signal itself is relatively simple. There are a number of FM transmission sites present all around Toowoomba, and with one being transmitted on-campus from the S-Block roof this was believed to be the largest peak of interest for this project.

2.2.6.3 Television Broadcasting Signals

Television Broadcasting can be found in the band called Ultra High Frequency, or UHF. This range extends from 520MHz to 820MHz, but most television signals are found from around 700MHz to 820MHz for free to air television.

Television broadcasting today has become more complex with digital television. All stations are trying to pack more information into the digital signals as well as keeping the old analogue signals which are compatible with the previous level of technology.

The television antennas in Toowoomba, unfortunately, are on the other side of the city and not easily accessible for this project with this equipment so are not thought of being a major signal of interest, even though they fit in the range and should have signals around the FM radio level.

2.2.6.4 Mobile Phone Communications

Mobile Phones have multiple signal ranges in which the transmissions can be found. The older technology utilised a range from 800MHz to 1GHz and so this lies nicely within our proposed project range. Unfortunately as stated this is the older technology and only a smaller percentage of phones today use a signal at this level. However it may be found that there are some peaks of interest for this range in some situations, and could prove to be significant for this experimentation.

The other mobile phone ranges range lies from 1.8GHz to 2GHz. This range includes all the latest technology, with the 3G network signals having signals found above the 1.9GHz range. This range would include a large number of signals very frequently for some testing sites but unfortunately these signals cannot be measured with a calibrated signal and so cannot discover any useful results.

2.2.6.5 Bluetooth Communications

Bluetooth was going to be investigated as an application of this project on the latest technology. Bluetooth phone compatibility has become standard for all phones today and is an effective, short-range way of transferring data fast between two devices.

Bluetooth operates at the 2.4GHz range and so could not be measured but the proposal was to use two blue tooth devices and transfer data between them, measuring the signal strength produced from these devices at different ranges and situations. This was going to be one of the main points of interest but unfortunately could not be measured due to the equipment limitations.

2.2.6.6 Private/Industry Signals

The last possible signals of interest are private/ government/ rescue service signals. These are licensed throughout the 30MHz to 1GHz range and include applications such as paging, taxi radio systems, police, fire, ambulance and rescue communications, council use, governmental use, industrial use, public transport communications as well as private use by anyone wishing to pay for the licensing.

The signals which were thought to be significant were the council, governmental, police and rescue services and taxi radio signals as these could be found throughout the city. The range of these signals could be found from 30MHz to 600MHz, with sub-ranges based around 30MHz to 80MHz, 120MHz to 250MHz and 450 to 600MHz.

The possible troubles with these signals are that they are very random signals, only used at various times and not effectively broadcasting non-stop such as radio and television signals. This meant that while the signals may be significant they could not be relied upon to be present at the time of testing.

2.3 History and Development

2.3.1 Early History

The earliest leap in the understanding of electromagnetic propagation and broadcasting came from James Clerk Maxwell in his mathematical equations in 1864 (Hecht, 2002). These equations were a massive development in many theories ranging from electricity, electromagnetics, optics, quantum physics and more. One of the major discoveries was the development that a wave could propagate through space. This would later be discovered to be at the speed of light which he was able to accurately predict using his mathematical equations.

The applications from these equations were many and varied. In 1988, Heinrich Hertz used two conductors to propagate a basic signal over a small distance of a few metres or less.

This was then further developed by Guglielmo Marconi in 1895. Using a battery, a spark generator, an induction coil and an antenna he was able to ring a small bell over a significant distance. This distance started from just a few meters but was able to be moved up to a kilometre and a half away and still the bell rang.

This signified electromagnetic wave propagation over a quite a large difference and between Hertz, and later Marconi, the basics of EM propagation was developed. In 1896 Marconi patented his invention as the first radio but this was overturned in the 1940's allowing Nikola Tesla to claim the first radio patent who was working on radio propagation at the same time as Marconi.

2.3.2 Radio Development

The first AM radio applications soon came into being. The first applications were in service on maritime vehicles for to help with communication while at sea. The first maritime application was a Morse-code signal that was sent between ships and shore (About, Inc.).

Lee Defroste developed a useful amplifier for radio applications and AM modulation, which is a technology still used today. The amplifier allowed for smaller signals to be detected which allowed a much longer distance of propagation to occur. He was also the first person to use the word 'Radio'. During America's involvement in the wars the government controlled all patents for the AM radio, to allow strict use by only their forces. This was a significant tactical advantage for the US and those allied with them.

Once the First World War was over radio was commercialised for radio broadcasting as a source of information transmission as well as a source of entertainment. At his time the radio was very wide-spread and its applications were many. During the Second World War the radio had to be used with care to not allow intelligence to be discovered by the enemy. This required the development of radio security as well as many codes.

The development of FM radio was then introduced in 1933 by Edwin Armstrong. This had the significant advantage of reducing the amount of noise in a signal but it wasn't until 1965 that the FM antenna system allowed multiple stations broadcasting at once.

2.3.3 Television Development

The first television development was in the late 1920's and was actually a mechanical television (Genova, 2006). This seems unusual but it contained a spinning disc with a neon light. The product of this was an image about 3 x 5cm and was blurry. It contained only 30 to 120 lines in the image with more being added as the early TV's were developed.

It wasn't until the 1930's that the all-electronic television was developed. This was the cathode ray tube television and was an all grey-scale picture, having no colour technology until much later in the development of television.

At this time televisions were not commercial and, while broadcasting could propagate for hundreds of miles, it was mainly only used for testing and for the select few rich enough to afford an early television.

The first commercial broadcasting was in 1941 in the USA. The history of broadcasting shows that some of the private broadcasting companies known today were developed during this mechanical television time, such as BBC in 1932. These were later developed into commercial stations, and have been developed into the stations that are known today.

By 1944, an inventor by the name of John Bairde exhibited his first fully electronic colour Television. It contained 600 lines and used a three colour interlacing to produce the final image results. In America, the first public colour televisions were distributed in 1950 and only broadcast for one hour a day for every day. This later developed into some night time programs due to public demand.

By late 1950 only 10 colour broadcasting towers were available so broadcasting was limited by distance and money. Slowly the colour coverage grew until coast to coast transmission was possible and by the late 1950's the colour television had become reasonable common throughout the wealthier population.

The colour television was only introduced in Australia in 1975, after black and white was introduced in 1950. This is a very late development compared to the rest of the world. Australia's networks grew slowly, but surely, and by the 1980's colour TVs were a common occurrence.

Today the industry is developing digital television to run at the same frequencies as analogue. There are a few free to air channels as well as the ability to pay for a large amount of extra channels. Digital broadcasting can now handle multiple cameras for the same footage, menu options and many special features not previously available, the most noticeable being the higher resolution. All these require higher bandwidths and total power in the broadcasting network, and so today the signals are a little higher than they used to be but are still kept significantly low by excellent compression of the data.

2.3.4 Mobile Phone Development in Australia

The history of mobile phone broadcasting in Australia (AMTA, 2008) started in 1981 when Telecom launched the first public broadcasting system. The typical handset cost $5000 to buy and was boot mounted.

In 1987 the first cellular system was introduced based off the current American Analogue model and was developed in the major cities. Handsets still cost around the $5000 range.

The first competition for Telecom was introduced in 1992 when Optus developed their first analogue system. By October there were 500,000 connections and most of these were still controlled by Telecom. At the end of the year Vodaphone became a licence provider.

In 1993 the first GSM network was created by Telstra, shortly followed by Optus and Vodaphone. GSM was a digital carrier which was superior to previous analogue technology but both were still used simultaneously throughout the country. GSM is still in commission today, looking to be phased out slowly in the coming years.

In 1994 one million analogue connections were completed and then in 1996 one million GSM connections had been completed. In 1998 Telstra announced the removal of the Analogue broadcasting, soon to be replaced by CDMA which was introduced in 1999. By the end of 1999 most old Analogue Broadcasting systems had been removed and by September 2000 the last Analogue shutdown was completed.

Until 2003 the current GSM lines were relatively unchanged. The development of internet through mobile phones was introduced as well as a few new network providers starting up. In 2003 Telstra initiated the new 3G network which is one of the newer developments today, allowing video calls, reasonable speed internet and streaming videos that require much higher bandwidth.

Developed more recently is the direct mobile to mobile known as infrared technology and Bluetooth technology. Mobiles speak directly from one phone to the other transferring data.

Another latest development has been GPS transmissions incorporated into mobile phones for accurate mapping and travel directions. Today there are millions of mobile phones being used every day. In 2005, 2006 and 2007, mobile phone sales were 8 million, 8.7 million and 9.2 million respectively. 9.2 million handsets are more than one phone bought each year in Australia for every three people [AMTA, 2008].

2.3.5 Today's EM Developments

Today there is a multitude of broadcasting sources. There are many different mobile systems working at the same time and CDMA is currently being phased out and the industry is moving more into 3G and next G mobile systems. As stated above these are much higher bandwidth signals. Also nearly all modern phones contain Bluetooth which is a short range data propagation system.

Today's radio system contains a multitude of FM and AM stations which are transmitted to cover almost all of Australia with every other country having its own national broadcasting. This broad coverage is able to provide all locations with the same levels of entertainment and news coverage. As well as this there are many private radio systems used by industries such as defence, police, emergency services, taxi services and shorter length radio systems.

In the last few years television has started with digital broadcasting as well as the old analogue version with both being transmitted over the same frequencies. There are many free to air broadcasts with more channels available for those willing to pay. Digital requires a larger bandwidth than analogue but allows a higher resolution and more options to be embedded into the data. Also wireless networks have been established for computer networks, especially in commercial applications. These wireless networks transfer data through EM signals rather than through the old wired systems.

All of these are examples of how these systems have been developed into what is known today. Quite often these broadcasting systems are taken for granted but each of these has their own signal frequencies and bandwidths and with so many broadcasting systems present today people are constantly exposed to electromagnetic radiation.

2.4 Health Concerns and Study of EM Radiation

2.4.1 Health Concerns with EM Radiation

2.4.1.1 Ionising Radiation

The first health concern with electromagnetic radiation has to do with Ionising radiation. Ionising radiation is classified as the EM waves which are Ultraviolet light, X rays and Gamma Rays. The high frequency of these EM waves means that more energy is stored within one photon of light (which is a packet of light). When these higher levels of energy collide with a particle they are able to strip electrons from the particle. The ability to do this becomes more significant as the frequency of the radiation increases, and so while Ultraviolet light only causes skin tans and burns, gamma waves are highly dangerous and cause radiation sickness and possibly death.

While ionising radiation has no effect on this project, there is a good reason why this description has been included here. This is the most dangerous type of electromagnetic radiation in our world. The difference between ionising radiation and non-ionising radiation is the frequency of the signal and this can influence on the belief of the dangers of non-ionising radiation. There is an implied belief that if this radiation is so dangerous, and there is only a small difference between this radiation and non-ionising radiation, then non-ionising radiation must have major health risks and concerns. However the health risks between these two groups should not be linked in any way as they are both completely separate and have different effects.

2.4.1.2 Non-Ionising Radiation

Non-ionising radiation is the radiation which is known as EM signals. This classification refers to visible light, infrared and radio waves. These are non-ionising as the photons do not have the energy sufficient to strip electrons from particles.

Non-ionising radiation can, however, causing heating of materials in which they come into contact, dependant on the strength of the field. There are interactions in which the electromagnetic energy excites the electrons, giving them more energy, which heats the body. However this effect has been minimised by the standards.

The limit stated in the current standards limits any electromagnetic wave to only a small fraction of the amount of energy required to heat tissue by 0.1ºC. There are 0.1ºC temperature fluctuations in the body within the normal body function and so there is no risk of heating causing any danger.

Heating is the most significant short term effect from non-ionising radiation and this has been eliminated by the standard restrictions placed on electromagnetic radiation. A lessor concern is that there is also electrical currents being produced throughout our body from EM radiation but this has only been theorised as a disturbance to deep sleep. Since this dissertation applies for public areas around Toowoomba there is no reason to follow up these effects.

The long term effects of low-level EM radiation are unknown and this is what causes concern in our community. Having no known effects on our bodies, it should be safe but the long term danger the largest concern with cancer and other effects on the brain and vital organs. The difficulty with long term exposure is that mobile phones, one of the main sources, are ever changing and being optimised, and the industry has only been public for around 21 years, with long term effects being in effect from 10 to 20 years.

Also in the beginning of the industry mobile phones cost around $5000, so even though it was public there were only a limited number of people which could afford one. Also there has been a boom in the mobile phone industry today and an increased use of mobile phones amongst children which has lead to a greater fear for the long term effects. The health risks which apply to mobile phones also apply to other electromagnetic radiation but currently mobile phones and their health concerns are the major topic of interest.

2.4.1.3 Current Concerns

The health concerns for this topic will be discussed briefly in this section before the literature is discussed later in full. Some concerns are as follows and whether these concerns are credible or not is still to be determined through scientific study.

The main concern is an increased risk of cancer from exposure. This increased risk of cancer can be located anywhere in the body but many concerns have been raised for specific types of cancer such as head and brain tumours, eye cancer, skin cancer and glandular cancers.

There are many concerns with increased or decreased heart rate with electromagnetic radiation exposure as well as blood pressure changes and many other vascular concerns. A general decrease in mortality rate has been a concern as well.

Concerns have been noted for the immune system and its overall effectiveness being decreased from exposure and hormone level imbalances being caused by EM signals obstructing the bodies regulating systems.

There have been reports of headaches, fatigue, restlessness, hearing loss, skin heating and irritation and many behavioural conditions. There have been many epidemiological concerns in regard to mobile phones as this is the main area of contact with EM radiation.

One of the main points of concern involves exposure of pregnant women and their babies to electromagnetic radiation. The possible concerns are birth abnormalities and defects are some of the more extreme concerns with EM exposure during pregnancy but other concerns are as simple as how EM exposure affects the gender of the child.

The risk increases when these concerns are associated with children and their developing bodies. Changes to a body as it grows, combined with the lower immunological levels of children lead to serious doubts as to whether it is safe. Exposure to children and small problems which may arise during childhood may be amplified in adulthood.

2.4.2 Private Scientific Studies

Some key scientific studies are reviewed in the following section and are a representation of the studies conducted to date around the world.

2.4.2.1 Previous Health Based Study Review

A literature review of the many experiments was conducted by James R Jauchem, from the Air Force Research Laboratories in the USA (Jauchem, 2007). The experiments were conducted from 1998 to 2006. They were reviews of research papers from many journals in well known US databases, such as The National Library of Medicines PubMed, BIOSIS, EMBASE, Toxicology Literature Online just to name a small number.

Some of the results that have been found are presented below. These results are not all conclusive but should be viewed as a guide to some current studies around. Used in this report is the term Radio-Frequency Energy (RFE).

**AM Broadcast Station workers having more abnormalities in resting heart rates compared to non-workers.*
**Lower heart rates in RFE plastic sealers.*
**A number of experiments showing no difference in heart rates, especially with mobile frequency exposure.*
**Lower mortality rates suspected in a number of occupational exposures.*
**Possible lower birth weights and higher risk of birth defects in Navy Personnel.*
**No credible evidence that low levels of RFE*
**Dispute as to Male/Female sex ratio in RFE exposures.*
**No alteration in sperm production with non-ionising RFE but sperm reduction if levels are sufficient to produce a temperature change.*
**Changes in the immune system: lymphocytes and leukocytes production.*
**a survey reports 13-31% of respondents in Norway and Sweden noticed a headache, fatigue, sensations of warmth around the ear or burning sensations in facial skin when exposed to mobile phones.*

**Many other epidemiological effects reported with cell phone use. Some were significant increases while others not being very convincing.*
**Reported no change in hormone levels with simulated cell phone exposure.*
**Others report higher levels of hormones from radio broadcasting RFE.*
**Mixed results with some hearing loss and other cases of no hearing loss from different RFE exposures.*

These are some results received from the literature review. It was stated by Jauchem that many of the articles he reviewed had biases, lack of evidence, circumstantial conclusions or did not weigh up the significance of results. The results of these journals were greatly variable, sometimes directly contradictory. This implies that these results should not be counted as conclusive.

This article was very useful in pointing out a number of the concerns that is felt in the scientific and medical community but at this time none of the results should be considered as true without full reviews of the experimental data. This does not mean results should be ignored but at this time cannot be given full credibility.

2.4.2.2 Cellular Telephones and Cancer – a Nationwide Cohort Study in Denmark

A study in Denmark is believed to be the most comprehensive in the world to date. This study conducted by C Johansen, J Boice, J McLaughlin, H Christensen and J Olsen was initially published in 2001 (Johansen et al., 2001).

The study involved the match up of two databases in Denmark. First the Danish Cancer Registry and secondly the National Board of Telecommunication. The Danish Cancer registry hold records of all cancer diagnosed and it was studied from 1943 to 1996. The Danish National Board of Telecommunication is the database containing all the mobile phone registration information and this was studied from 1982 to 1996.

The first study looked at the increased incidences of rare cancers, such as ocular melanomas in today's society. In the last 54 years there has been no increase in this type of cancer, or other similar rare types. This was calculated through the percentage of people on the cancer register with rare types, comparing this rate over time.

The second part was a comparison between the two databases, trying to find links between mobile phone users and cancers. Through complex analysis between the two databases it was possible to determine the cancer rates of people and to determine how the cancer rates of the 90's compared to yesteryear.

The databases contained people that had very little mobile phone experience to a large amount of experience. It was recorded that a few people had 10-15 years mobile phone exposure. No increase in cancer could be recorded due to mobile phone usage from the databases and no increase in rare cases of cancer could be attributed to mobile phone use.

A follow up study was conducted by many of the same people, C Johansem, J Boice, J McLaughlin, R Jacobson, J Schuz and J Olsen called Cellular Telephone Use and Cancer Risk: Update on Nationwide Danish Cohort. The registries were expanded up until the year 2001 and more specific cancers reviewed (Schuz et al, 2006).

It was found that mobile phone use was not specifically associated with an increase in brain tumours, acoustic neuromas, salivary gland tumours, eye tumours or leukaemia. These were investigated due to the localisation around the head area. From the 420,095 people on that were viewed on the mobile phone registry the number that developed cancer was 14,249. This was lower than the predicted cancer level of 15,001 from national cancer rates. However there is no biological plausibility to classify this as causing a decreased rate of cancer.

2.4.2.3 Meta-analysis of long- term mobile phone use and the association with brain tumours

This study published and accepted in 2008, and was published in the International Journal of Oncology – Vol. 32, No. 5 published in May 2008. It is based on the statistical analysis of a number of other studies which previously researched into the effects of Electromagnetic Radiation and the resulting Ipsilateral Glioma and Acoustic Neuroma, two types of cancer (Hardell et al., 2008).

The data received from other studies was combined and analysed as a whole to see if any strong trends emerged throughout multiple studies. This is a consolidation and analysis of more data in the hope of seeing a trend emerge from multiple studies.

This can have the positive effect of looking through multiple lots of data and studies and reducing the risk of errors through having more data to rely on. On the other had it could be believed that in fact the cross-examination of multiple studies leads to the multiple sources of error being adopted from each, thus losing credibility through trying to combine multiple studies which cannot be combined.

While there are advantages and disadvantages, if the original sources were under proper scientific scrutiny and are able to be seen as high quality studies the results should lead to a positive outcome of reduced error and be able to show that multiple studies all lead to a conclusion in which a trend emerges.

The resulting trend discovered was that there was an increased risk of Ipsilateral Glioma and Acoustic Neuroma being caused by mobile phone radiation.

The increased risk of Ipsilateral Glioma was believed to be around 2.4 times the rate of normal levels but Contralateral Glioma was believed to be only 1.2 times the rate of normal levels. These levels were representative of more than 10 years exposure to mobile phone radiation.

For the results of the Acoustic Neuroma the rate was 1.3 times the normal levels for greater than 10 years exposure. These patterns were recognised as being consistent throughout the many studies and so an increased risk can be concluded from this study.

2.4.3 Governmental Research

There are a number of initiatives which have been put forward by the government in regards to electromagnetic radiation research. These were initiated as ways to improve our knowledge of EM radiation and understand the dangers of electromagnetics.

2.4.3.1 Australian Electromagnetic Energy (EME) Program

This was a program initiated in 1997 and committed more than $1 million per annum to research in this area. There have been a number of stages during this program, each providing key researchers with funding to investigate different areas of concern. (Australian Radiation Protection and Nuclear Safety Agency, 2003, online recourse)

2.4.3.1.1 Stage One

The first stage of the program provided funding to 4 independent research projects, including two pilot studies, with funding, with a total of $1.4 million being spent for this stage.

The first project was conducted by Professor Bruce Armstrong and was the pilot study initiated into the effects of RF EME on brain tumours and other tumours. This was based around the personal use of hand-held mobile phones and looked at increase risk of cancer in tissue vulnerable to the electromagnetic energy.

This pilot study was reviewed and was extended into a four year full study with a grant value of $1.2 million but no publications have been made on this study.

The second study to be granted money was Dr Con Stough's group who conducted an 18 month study on the effects of RF EME on concentration, attention, problem solving and memory.

The study contained a number of tests, each testing a key skill and tested two groups of volunteers of various ages, sexes and educational backgrounds. One group was given significant electromagnetic exposure and the other group a scam electromagnetic exposure.

The results from this implied that RF EME from mobile phones had some influence on cognitive abilities. It was stated though that both improvements and impairments in the cognitive ability were found from the effects of this radiation exposure. The journal published for this report is titled 'Neuropsychological sequelae of digital mobile phone exposure in humans' (Keetley et al., 2006)

The third was a pilot study linking RF EME with DNA breakages and was to be studied in mice. This was unsuccessful and failed to receive extra funding.

The final study of the first stage was conducted by Professor Barrie Vernon-Roberts' group who studied cancer rates on genetically modified mice. Through exposing the mice to 898.4MHz signals it was studied the development of cancer in the mice and found that there was no increased risk over a 1.5 to 2 year period. The study has been published in the paper titled 'Long-term exposure of Eμ-pim-1 transgenic mice to 898.4 MHz microwaves does not Increase lymphoma incidence' (Utteridge et al, 2002).

2.4.3.1.2 Stage 2

The second round of funding involved two studies.

One was awarded to Dr Andrew Wood's group, who was a part of Dr Con Stough's group from the first round of funding, and involved more effects on cognitive and mental conditions from mobile phone frequency signals.

This study was expanded to the affects on brain reactions, sleep patterns, the biological clock, response to visual and auditory stimulus and other human performance factors. This was conducted over three years and six journal articles have resulted, with varying results, in favour of and against electromagnetic radiation.

The second study was awarded to Associate Professor Paul Mitchell's group and was a two year study on the effects of long term mobile phone exposure on vision and hearing. Results from this study could not be acquired.

2.4.3.1.3 Stage Three

The third stage involved a long term involvement of five years and would provide $500,000 a year to the Royal Melbourne Institute of Technology (RMIT), Australian Centre for Radiofrequency Bioeffects Research. This is an open-ended grant allowing for the continual study and development of new research and ideas from the RMIT.

So this has been the government funded initiatives around the late 90's and early 2000's.

2.4.3.2 World Health Organisation (WHO)

A WHO facts sheet is available on mobile phones and public health concerns. WHO is an international organisation which reviews world health issues, releasing publications and recommendations in regard to these issues. The facts sheet published contained information on the many health risks and what has been concluded in a number of research articles (World Health Organisation, online resource).

Research has clearly shown an increased risk of driving while using a mobile phone, either with a handheld device or a hands-free kit. There is also the risk of electromagnetic interference between mobile phones and medical devices such as pacemakers and hearing aids.

There are many effects which have been reported from research such as changes in brain activity and sleeping patterns. Also reaction times and decision making may be affected but many of these have to this day only been concluded as small and insignificant in terms of being a health risk.

The main risk is believed to be cancer risks. The facts sheet released by WHO stated that current scientific evidence show that exposure to RF fields and mobile phones is unlikely to induce or promote cancer. While many studies exposing animals to RF fields have found no evidence that EM radiation causes brain cancer, one study, in 1997, has found that an increased rate of lymphoma was determined from RF radiation in genetically engineered mice. The implications of these results are unclear and studies into epidemiological studies also have shown no convincing evidence of increased risk.

2.4.3.3 International Commission for Non-Ionising Radiation Protection (ICNIRP) Guidelines

The ICNIRP guidelines are the guidelines that our Australian standards are based on. The guidelines contain the standards and why they were developed, including the scientific and mathematical theory as well as the research studies (International Commission for Non-Ionizing Radiation Protection, 1998, online recourse). The ICNIRP guidelines are discussed further (Section 2.5.2.3, page 39).

For levels of radiation from 100kHz to 300GHz a number of research studies were analysed for this guideline. Reproductive studies which were analysed had many results which were both positive and negative. These studies suffered from small sample sizes and poor records of exposures and so were often not credible. There were a few notes of higher levels of miscarriage and the possibility for birth defects but there were also many studies which stated that no evidence was found concerning reproduction rates.

The amount of studies reviewed by ICNIRP concerning cancer was low due to number of studies available at the time of writing (1998). The studies that were discussed had no real evidence to conclude the effects of electromagnetic radiation causing cancer.

A number of military studies, and studies of location specific exposures could not conclude any cause of cancer besides two where the results were difficult to interpret and the studies poorly defined. The final result was that no cancer risks could be concluded.

The studies which defined the ICNIRP guidelines recommended values were based on volunteer studies. These studies involved volunteers being exposed to high levels of 100kHz to 10MHz radiation. The reported results were nerve and muscle stimulation at 100kHz which led to a feeling of muscle tingling. When the frequency was increased up to 10MHz the same strength caused a sensation of warmth. Signals above the 10MHz frequency resulted in stronger burning sensations to occur.

The standards then defined based on these levels results as the levels of heat were found to be rises of around 1ºC to 2ºC which can cause serious concerns to the human body.

2.4.4 Scientific Results

It is currently recognised that above the ICNIRP recommendations which is adopted by many nations the effects of electromagnetic radiation are short term heating or muscle twitching. The standards that are in place today (Section 2.5.3, page 41) state the standards and these standards are set at a level that there are no dangerous short term effects. The current standards can be concluded as being at the right level to allow for safe use with no short term effects.

The concern today is whether or not long term levels of low-level radiation have any known effects. The scientific community is split between the belief that there are definite effects and risks and the belief that people are overreacting and at these low levels there is no risk or danger. Also until there is conclusive evidence of any effects of long-term EM effects it is impossible to change the standards in any way to take into account these long-term effects as the safe requirements cannot be known.

There have been large amounts of studies over the past few years related to cancer and there are many studies which say that there are effects and increased risk of cancer. However there are also many studies which support that there is no evidence of cancer increases, including the study in Denmark of over 420 000 people on the mobile phone register.

The Australian Electromagnetic Research Program, put forward by the government, funded many studies but the results from these studies were in favour of the fact that there is little evidence to prove the increased health risks from electromagnetic radiation. These studies fall under a greater scrutiny than those of privately funded studies and can be believed to be more credible studies in general but in the long term all it takes is one irrefutable amount of evidence that there is a health risk and it may concluded that it is true.

The problem that is faced now is that poor practices, analysis, theories and instrumentation can all cause false positives or true negatives and a large amount of studies which have conflicting evidence and are unable to conclude which results are a true representation of the truth.

For this reason the Denmark study using the Cancer Registry and the Mobile Phone Registry seems to stand out as the most credible source because of the extensive sample size of people surveyed/tested. The Danish registries were well kept records which have been in place for long periods of time, which are the key points lacking from a number of long term exposure studies.

The complications of the Cancer and Mobile Phone registry study is that it has difficulty isolating the samples and so is based on a large sample size leading to accuracy rather than sample control but in this sort of situation it appears to be possibly one of the best testing situations which can occur.

2.5 Authorities and Standards

2.5.1 Standards Authorities and Organisations

There are a number of key organisations involved in the standards and regulations surrounding electromagnetic radiation. The standards are ever evolving and, in general, research into electromagnetic radiation is shared internationally and analysed as to its effects and problems.

2.5.1.1 International Commission of Non-Ionizing Radiation Protection (ICNIRP)

The ICNIRP is a group of professionals that are elected from throughout the world. The members represent the leaders in the field of Non-Ionizing Radiation study and, upon selection into ICNIRP, no longer represent their country or institutions to allow for a non-biased board to address issues raised in this area of science.

The ICNIRP currently contains 14 members and covers all areas of Radiation exposure, from Optometry, to Biology, to Epidemiology. The Commission is broken down into separate committees, containing more members, which cover each area specifically. These areas are Epidemiology, Biology, Physics and Engineering and Optics.

Through the Commission and the sub-committees ICNIRP achieves its goals of analysis of Non-Ionizing Radiation through stringent and specific means. Reviews of current Literature in each given field is continually conducted, allowing for ICNIRP to stay up to date with all the current developments and make decisions which are based on a solid knowledge base of the world's scientific community. These committees then form reports on these topics and present this data to the main commission for analysis.

End products produced by the ICNIRP are their many publications. These publications are usually in the form of Guidelines, Statements or Reviews but can also include many other forms of presentation.

Guidelines are a detailed guide of the risks and limitations that should be placed on a certain product, environment, etc in regard to a certain concern or issue. One such example is 'Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)'. These guidelines are free for use by anyone who is interested and are often used in the development of country standards. Australia's own electromagnetic radiation standards are based on ICNIRP guidelines.

Reviews are often literature reviews given out at semi-regular intervals to the community. These provide a review of recent research and the results and can become the instigating factor of further investigation. The statements provided by ICNIRP are similar to the guidelines that they provide but are usually shorter and more focused on a general topic as it arises. They are used to address concerns that have been raised in the short term and alleviate some of the questions that arise. One such statement is ‘Statement on Medical Magnetic Resonance (MR) Procedures: Protection Of Patients.’

2.5.1.2 The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA),

‘The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), as part of the Health and Ageing Portfolio, is a Federal Government agency charged with responsibility for protecting the health and safety of people, and the environment, from the harmful effects of ionising and non ionising radiation,’ (Australian Radiation Protection and Nuclear Safety Agency, 2008, online resource).

ARPANSA is the governmental agency in Australia that deals with all issues relating to Radiation and Nuclear Sources. ARPANSA is similar to ICNIRP, but studies the effects and relates them to Australia.

ARPANSA is a government agency first formed in 1997 from a merger between Australian Radiation Laboratory (ARL) and Nuclear Safety Bureau (NSB). The Australian Radiation Laboratory was in charge of research and reporting of the effects of radiation on health, the environment and other issues and the Nuclear Safety Bureau was the body in control of our two research nuclear reactors in Sydney.

ARPANSA acquired these responsibilities and more upon the merger, become the main source of Australian Radiation and Nuclear research, regulations and governmental advice.

ARPANSA developed the ARPANS Act 1998 which is a document outlining the application of safety and restrictions on exposures for many types of radiation. It also contained information on such things as the licensing, codes of practice and regulations.

ARPANSA has developed the standards and codes of practice in regards to ionising and non-ionising radiation. ‘Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3kHz to 300GHz (2002)’ is the standard developed for non-ionising radiation exposure.

This standard is to be followed by any Electromagnetic Radiation producing company or individual. The levels of RF EMF exposure outlined in this document are based directly on the ICNIRP 1998 guidelines. These guidelines have been altered to be used in practice and have been developed to contain all possible situations for the standard use.

It is not ARPANSA’s responsibility to regulate these standards in most situations. ARPANSA may be required to investigate any federal matter which may arise but these do not occur often. The regulation of the standards falls upon State and Territory Departments as well as ACMA, who has regulatory authority over public and private broadcasting as well as communications. The relevant state authorities are as follows:

ACT	ACT Health: Radiation Safety Section
QLD	Department of Health: Radiation Health Unit
NSW	Department of Environment and Climate Change: Hazardous Material and Radiation Section
VIC	Department of Human Services: Radiation Safety
SA	Environment Protection Authority: Radiation Protection Division
NT	Department of Health and Community Services: Radiation Protection Section
TAS	Department of Health and Human Services: Health Physics Unit
WA	Government of WA: Radiological Council

2.5.1.3 Australian Communication and Media Authority (ACMA)

ACMA is the regulatory body in charge of anything relating to Broadcasting, Radio communications, Telecommunications and the Internet. ACMA was established, in July 2005, as a merger by the Australian Broadcasting Authority (ABA) and the Australian Communications Authority (ACA). In this regard ACMA is now the only Authority which covers all of these areas.

ACMA's authority covers all the Communication and Media industry, from the signal production, transmission safety, licensing and public and industrial safety in regard to signal transmissions. Also they cover media content and journalistic integrity, telemarketing, censorship, product delivery and quality and overall media authority.

"ACMA has the regulatory Responsibility to protect the health and safety of persons exposed to RF EMF from telecommunications transmitters." (Australian Communication and Media Authority, 2008, online resource) ACMA has adopted the ARPANSA standards in regard to radiation exposure. They are able to take action upon anyone breaching the regulations and provide advice to companies and consumers about their roles, rights and responsibilities.

ACMA also is the licensing authority for broadcasting and controls the frequency and bandwidth of all broadcast signals across the whole EM spectrum. This includes private broadcasting and public broadcasting and puts limits on the content of this broadcasting, the area in which it can be used, the maximum amplitude of the signal, the purpose in which it is used, the duration of use and many other variables which may impact the safety or performance of a broadcast.

2.5.2 Standard Documentation

2.5.2.1 Current ARPANSA Standards

Radiation Protection Standard: Maximum Exposure Levels to Radiofrequency Fields – 3kHz to 300GHz. Radiation Protection Series No. 3. (Australian Radiation Protection and Nuclear Safety Authority, 2003, online resource)

This standard was approved on the 20th March, 2002 and advised for use on the 12th April, 2002. Corrections were made in the Errata issued 8th May, 2003.

This document is the current standard, enforceable throughout Australia, and relevant to all situations throughout our country. It puts forward restrictions which apply to public exposure situations, as well as occupational situations. It covers long-range signals, covering the whole body, or short-distance signals covering only part of the body. It states the measurable values which are used to confirm the max level to these standards.

The standard contains tables with the standard values and also many more tables containing information in regards to standard variables and influencing factors which directly affect electromagnetic radiation strength. It contains the history of the Australian standards, as well as the scientific derivation of the standards.

As well as the actual standard information, the method of standard compliance is also discussed to help those in the industry to meet these requirements. This involves how to manage the risks for occupational exposures, and then the resulting public exposure. Also it gives approaches on how to verify this standard compliance, so those producing the exposure can be sure they have met these standards.

It contains in-depth information on the way to evaluate and record the relevant data. Also protection in terms of risk management, source control and reduction, training, medical and overall assessment. It also has steps to follow for contacting authorities.

Recommendations and National Standard – Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002) (Australian Radiation Protection and Nuclear Safety Authority, 2002, online resource)

This standard provides restrictions for ionizing radiation, and is the counterpart to the standard issued for non-ionizing radiation which was explained above. This standard affects the safe levels of nuclear radiation, which is highly dangerous above the standard, and also provides recommendations on how to meet these standards.

This is the standards for the rest of the industry that ARPANSA covers, but does not hold a direct application to this project.

2.5.2.2 The ARPANS Act

Australian Radiation Protection and Nuclear Safety Act No. 133, 1998. (Australian Radiation Protection and Nuclear Safety Authority, 1998, online resource)

This standard has been used since 23rd of June, 2008. Previous versions of the acts have been in place since 1998.

"3 Object of Act: The object of this Act is to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation." ARPANS act, 1998 (Australian Radiation Protection and Nuclear Safety Agency, 1998,online resource)

The act is the document which defines how ARPANSA is formed, issues the standards and is the main document that ARPANSA needs to conform to when becoming the authority for electromagnetic radiation. It has been put forward by the federal government, prepared by the Office of Legislative Drafting and Publishing, Attorney-General's Department, Canberra.

2.5.2.3 ICNIRP guidelines

Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz) (International Commission of Non-Ionizing Radiation Protection, 1998)

Published by the International Commission for Non-Ionising Radiation Protection in Health Physics 74 (4): 494-522; 1998.

As stated by the title these are guidelines, issued by the International Commission for Non-Ionizing Radiation Protection, in regard to electromagnetic fields. This is the culmination of years of study into all of the effects electromagnetic radiation, and is a guide onto what are the safe levels of non-ionising radiation.

These guidelines hold no official power, but are recognised as the leading experts in this field, and have been adopted by many bodies of government as standards. In this regard this document is the most important document for electromagnetic radiation exposure, as it not only influences the governing of one nation but many.

The guidelines first cover the science behind the electromagnetic fields, and how these apply to strength and effects of the radiation. It covers all developments and any issues which effect radiation levels.

It contains a review of many key studies, which directly contribute to what is known today about electromagnetic fields. These mainly were medical experimentation as this had the biggest influence on the limiting factor of safe levels. Studies, such as cancer research,

There is an increased risk of cancer in situations of higher strength, and lower frequency. Many of these were occupational in extreme situations but it was discovered that at high strengths it was possible.

Also a study on animals concluded that below the level that was recommended as the standard, 4W/kg for a localised signal, tissue heating was well under 0.1ºC. This is easily acceptable levels as different areas of our body change temperature by more than this throughout our natural day.

The guidelines tell the recommended level for all exposures, public and occupational. Also it contains recommendations on the full body exposure, as well as the more local exposures, directed at smaller body areas.

2.5.2.4 Previous Australian Standards

Interim Australian/New Zealand Standard – Radiofrequency Fields, Part 1: Maximum Exposure Levels – 3kHz to 300GHz. AS/NZS 2772.1(Int):1998. (Standards Australia, 1998)

This document originated as AS 2772.1 – 1985.

This is the standard document from 1985, in regards to electromagnetic radiation exposure. This is the document which preceded the *Radiation Protection Standard: Maximum Exposure Levels to Radiofrequency Fields – 3kHz to 300GHz. Radiation Protection Series No. 3.* released by ARPANSA.

Preceding the current standard, it contains the old restrictions, from 1985 to 2001, which were to be enforced in all situations. The standard contains much of the same information as the current standard, including the scientific calculations and information. It contained health risks and effects of the exposure limits as well as all this information for all different situations.

Australian Standard – Radiofrequency Radiation, Part 2: Principles and Methods of Measurement – 300kHz to 100GHz. AS 2772.2 - 1988. (Standards Australia, 1988)

This is the second part of the standard, put into effect 3 years after the first part. This document should be used with AS2772.1, part 1, which is the actual standards, and using the methods in part 2 to follow the standards in part 1. It is less a standard, but rather a guideline for testing and measurements. This document stated how to know what the standards are, and how to measure fields, allowing anyone to know they are not exposed levels above the standard.

It explains how to do the measurements, which instruments to use, and for which situations they are recommended. It explains the difference between near field and far field radiation. It explains the simplicities of far field measurements, and the much harder measurements of near field measurements. It contains what may happen to the measurements in near field, how accurate they can be, and how to improve the accuracy.

How to do the measurements uses choice of a probe, the procedure for the measurements, instrumentation usage considerations, sources of error, calibration as well as much more information, useful for all occupations dealing with electromagnetic fields.

2.5.3 The Standards

As stated in (Section 2.5.2.1, page 38), the standard document currently in use is ‘Radiation Protection Standard: Maximum Exposure Levels to Radiofrequency Fields – 3kHz to 300GHz. Radiation Protection Series No. 3’, released by ARPANSA. So what are these standards and how do they apply?

2.5.3.1 The Standards Values

Table 2.2: Australian Standards - Basic Restriction for whole body average SAR and spatial peak SAR (Australian Radiation Protection and Nuclear Safety Agency, 2003)

BASIC RESTRICTIONS FOR
WHOLE BODY AVERAGE SAR AND SPATIAL PEAK SAR

Exposure category	Frequency range	Whole-body average SAR (W/kg)	Spatial peak SAR in the head & torso (W/kg)	Spatial peak SAR in limbs (W/kg)
Occupational	100 kHz–6 GHz	0.4	10	20
General public	100 kHz–6 GHz	0.08	2	4

NOTES:

1 For comparison with the limits in Table 2, the measured or calculated SAR exposure level should be averaged over any six minute period.

2 Whole body average SAR is determined by dividing the total power absorbed in the body by the total mass of the body.

3 Spatial peak SAR averaging mass is any 10 g of contiguous tissue in the shape of a cube.

This table gives the bare-bones basic standards that apply for all frequencies from 100kHz to 6GHz. Looking at this table more closely it is needed to fully understand each part.

2.5.3.2 Occupational Exposure Category

Occupational exposure in this standard is classified as:

"For the purposes of this standard, occupational exposure is defined as exposure of a RF worker (as defined) to RF fields when on duty." (Australian Radiation Protection and Nuclear Safety Agency, 2003)

And an RF Worker is defined as:

"A person who may be exposed to RF fields under controlled conditions, in the course of and intrinsic to the nature of their work." (Australian Radiation Protection and Nuclear Safety Agency, 2003)

Occupational exposure applies to any workers who are exposed to controlled levels of Radio frequency fields which apply to work. So this does not include people who do not know they are exposed to signals, or those who are exposed to signals from nearby, but external sources, as close as the neighbours. And so all occupational workplaces must be aware that outside of their controlled property it is no longer classified as occupational.

Also to have a workplace covered under the standard as occupational they must have control measures in place for the electromagnetic fields.

2.5.3.3 General Public Exposure Category

General Public Exposure in our standards is classified as:

"All exposure to RF fields received by members of the general public. This definition excludes occupational exposure, exposure of aware users, and medical exposure. It is recognised that some persons may need to transit controlled areas (as defined), and this is permitted under adequate supervision." (Australian Radiation Protection and Nuclear Safety Agency, 2003)

General public is defined as being everyone not covered by occupational exposure, medical exposure (self explanatory as a patient of medical diagnosis or treatment) or being an aware user (any person who is trained and aware of using such devices which may have a higher electromagnetic exposure level).

2.5.3.4 Occupational Against General Public.

All occupational exposure levels are five times more than general public levels. These higher exposures are due to the occupants being more highly trained, aware of the higher levels and willing to work under these conditions, only exposed to them for a maximum of a working day and the signals being under controlled conditions.

2.5.3.5 Whole Body SAR Standard Value

As seen on the table the standards for whole body average SAR values are 0.4W/kg and 0.08W/kg. For the definition of SAR refer to (Section 3.3.2.1, page 68). The whole body average is applied to far-field electromagnetic signals, or signals from a distant source, where all the radiation which a person is exposed to is very constant over a whole body.

These values are measured as an average over six minutes and the final value of SAR can be determined by using the power absorbed divided by the total mass of the body.

This is the standard which is used for this project. The 0.08W/kg value is used for General Public Exposure over a Whole Body Average SAR value. This applies to all signals from transmission towers; FM, AM, TV Broadcasting, mobile phone base stations and any other far signal sources. Also it covers signals from distant mobile phone handsets and other distant telecommunications.

2.5.3.6 Spatial Peak SAR Standard Value

The spatial peak SAR standards are used for near-field signals. These signals are very close signals, such as mobile phone handsets, close electronic leakage, other hand-held communications and any other signal that is very close to exposed people.

The standard is broken up into Spatial Peak SAR in the torso and head, and in the limbs. The head and torso contains more important anatomical functions than the limbs and have an SAR limit of 10W/kg, occupational and a limit of 2W/kg for public exposure. SAR standards for the limbs are slightly higher, set at values of 20W/kg for occupational and a limit of 4W/kg for public exposure.

Once again the Spatial Peak SAR value is averaged over six minutes, but also is taken in the worst case 10g cube of tissue in any one spot.

There is the possibility that near-field signals will be encountered during this project in nearby mobile phones and electronic leakage. There is little that can be done about this as to measure near-field signals requires a very small antenna, able to pick up peaks over a very small area in an ever-changing field.

Also a very high understanding of short range fields and the field source is required to determine where the peaks are and quite often cannot be measured in a real-world situation, instead being measured in controlled situations.

2.6 Public Perception and the Media Spotlight

In recent times electromagnetic radiation has been in the public spotlight. At least mobile phones are a very hot topic at the moment with stories frequently appearing on many media platforms.

"Commencing in 1996, the Government provides 1 million dollars per annum for the Electromagnetic Energy (EME) Program. This program supports research into and provides information to the public about health issues associated with mobile phones, mobile phone base stations and other communications devices and equipment. The program recognises public concern, and the need to ensure standards and public health policies continue to be based on the best available scientific information. The program is funded by a levy on radio communication licensees collected by the Australian Communications and Media Authority (ACMA)." (Australian Radiation Protection and Nuclear Safety Agency, 2008)

This is a statement by ARPANSA in their public facts sheets, which recognises the publicity that electromagnetic radiation has achieved, and since the time of writing this has only gotten larger, with massive growths being present in many industries leading to higher levels of concern.

2.6.1 Media Articles

One report that occurred during this project was a story broadcast on 'Today Tonight' titled "Mobile Phone Tumour Fears" broadcast June 12, 2008 (Sparkes, 2008). This story contained two people who were diagnosed with cancer which they labelled the effects of mobile phone use. It is not known whether these effects are true but no scientific research or evidence was referred to.

Another study in support of the risks of EM radiation was published by the ABC news, 23rd of August, 2000 which was related to Electromagnetic exposure in working conditions and its relation to suicide. 'Suicides linked to electromagnetic radiation' (Salleh, 2000) stated that a study by University of North Carolina, and further published in The Western Journal of Medicine, where almost 140,000 electricity workers were analysed. This news report was quite factual and even stated theories of inaccuracy for the project, and so was very informative and credible. The result from this was that there was a link between electricity workers and higher risks of suicides but there were a number of effects which may influence this.

The Herald Sun, 9th of November, 2007, published 'Wireless gadgets poisoning your home?' (Cogdon, 2007). This article was aimed at the viewpoint that mobile phones and wireless communications could be dangerous. Unfortunately there was once again no studies quoted, and the article spent most of its time saying that other studies have found no evidence in regard to electromagnetic exposure risks but these studies are not accurate enough to be relied upon.

The only situation which was presented in regard to this topic was stated as follows:

‘A series of tumours in staff at an RMIT building in Melbourne was last year linked to electromagnetic radiation from mobile phone towers.

The 13 staff worked on the top two floors of the Bourke St building under two mobile phone towers, but an occupational health and safety report found the building was safe and ruled out a cancer cluster.’

This statement was contradictory and the experts that were quoted stated many viewpoints without the article providing reasoning. In this regard the report appeared to also have negative connotations towards EM radiation, without providing reliable evidence.

One report was entitled ‘Japanese study clears mobiles of brain cancer risk,’ which was published on the 5th of February, 2008 by Reuters (Hirschler, 2008).

This was an article on a Japanese study, conducted by the Tokyo Women’s Medical University, and published in the British Journal of Cancer, which studied a large number of cancer patients, and analysed the likelihood of the cancer being related to mobile phones. It found no evidence of such a link and while this is an informative report, linked to a real published study unfortunately this media story is the minority, not the majority.

2.6.2 Public Perception

What has been provided above is just a small snapshot of a few articles from newspapers and television. It is hard to reflect the whole media perception from such a small sample but there are a number of trends able to be seen in the media. The number of negative stories for mobile phones and electromagnetic radiation vastly outweighs the number of the positive stories. The stories which are provided as negative are, as often as not, unsupported by any study, and in the scientific community, should be considered as being inaccurate.

This does not mean that all negative articles are worthless, but they need to be looked at a little more closely to see what they are actually stating as fact and what evidence they quote. Unfortunately the general public is not scientifically minded and so does not often do the research required after hearing these stories to see the validity of its claims. Some articles, such as ‘Suicides linked to Electromagnetic Radiation’, by the ABC, which was stated above, did provide backing evidence, and these should be given as much weight as any other articles which provided evidence.

It was found that any positive articles are most often written in association with a study which was concluded and published, and so with the backing of the publishing journal can be seen as verified that the claims have some basis. Unfortunately due to the small amount of positive articles they are not given the weight they deserve by those who read them.

2.6.3 Recommendations for those Concerned

As a recommendation to those who view the media articles and are concerned in regard to the topic of electromagnetic radiation, they should analyse each article as they view them.

Does the article quote a scientific journal, as these journals analyse the validity of any experimentation and are unbiased as to the results? If they do then one can be assured that the experiment itself was well conducted.

Remember to search for other journal articles that cover the same topic. Often there are a number of experiments which cover the area and the conclusions of many scientists will be apparent, rather than just a few.

Do not take quotes by professionals as the verdict of the entire industry. They are only one person in an industry containing many professionals.

Professionals that are the head of reputable organisations will also put forward the view of the organisation, and so do not make quotes without fully investigating the subject at hand and weighing up the ramifications of the quote. They also will choose not to comment on areas not under their area of expertise.

Media articles should always be taken at face value and cannot be held as truth without further self investigation. It is up to the reader to decide on their own belief on the topic, and should not be swayed to any decision from viewing just a few media articles.

2.7 Background Information on Project

2.7.1 Project Description

The information given in Appendix B (page 117) is what was stated in the 2008 project offering. From this information some project requirements can be seen. Provided in Appendix A (page 116) is the project specifications which was the result of some discussion and analysis of the project description. These are the specifications on which this dissertation is based.

The task for this project is to research electromagnetic (EM) radiation, in particular the radiation that is purposely produced in our telecommunications and broadcasting industry. Research is to be conducted into what electromagnetic (EM) exposure is likely to be present in public, the possible health implications from these EM exposures, their standards and limitations and what the overall effects of these should be on the community.

Some measurements are required to be completed that represent the typical exposure of this in public, and in work places, around the USQ campus and compare these to standards and health research. This data should allow insight into how the standards are being followed and any possible dangers, whether known or unknown that may arise from the project.

2.7.2 Project Requirements Development

From this broad topic description it is possible to further develop the requirements. The first part is to see what EM radiation should be present in our environment. The main sources are TV broadcasting, Radio, Mobile Phones and 50Hz power line radiation as well as a number of lesser recognised signals, such as taxi networks, emergency services radio, airport control signals, short distance signals (ie. TV remote control, Bluetooth, etc.).

From recognising these sources predictions are to be made as to which of these people will be exposed to and discover relevant standards for each of these sources. From these standards there should be development of an understanding of the effects of these and limitations that the providers have when producing these.

Studies into the health risks of electromagnetic radiation is an important aspect of this project, as the health risks/benefits are one of the major community concerns on this topic. Therefore the public concerns that have been voiced and also what scientific concerns have been voiced by the science community should be analysed. These are able to be found from a number of journal articles, public announcements and news articles relating to this issue. From the health risks that are discovered there will be sufficient information to be able to weigh up these and relay how significant they are in today's public.

Once this research has been completed the practical work is to commence. Measurement of EM radiation strength is to be taken in a number of real world situations based around the USQ campus and nearby Toowoomba areas. A few examples of this could be Radio Transmitters, Mobile Phones and Electrical Equipment. The measurement methodology is important so it must be designed with all the information gathered to allow for the most complete experiment as possible.

From the gathered data from the measurements it is required to discover if the current standards are being followed. It is also a requirement to work out the total exposure of the occupants of these places throughout a 'working day' or for the total time of their exposure. The results of these should be weighed up as a total risk and the overall health implications should be reviewed. Lastly a conclusion should be finalised and address any concerns which were brought up throughout the dissertation. The results may need to be of a quality to present to the public.

2.7.3 Ethics and Consequences.

'Human Exposure to Electromagnetic Radiation' as a project has a highly ethical standpoint. This is a project that has been developed from public concerns of the topic of Electromagnetic exposure. There have been many reports on this subject and many have been inconclusive or unconvincing in the argument that electromagnetic radiation of any sort is unsafe.

The current standards that have been developed provide a framework to the allowance of electromagnetic waves in public and have provided a level of safety in the public eye. The question is then raised, are the standards being followed? As well as this, have the standards taken everything into consideration? These questions are the concerns that many may have and information provided may be cause for alarm if the results are unsatisfactory.

The ethics of this topic are two fold. To inform the correct authorities if any anomalies have been found or standards are not being met. These standards are enforceable by law and can carry a penalty of up to $550,000 for first time corporation offenders. As such any breach of the standards must be reported to the correct authorities at first possible convenience. This in turn allows the authorities to provide the protection needed for the public in this situation.

This dissertation should be available to the public of Toowoomba, or more specifically those who spend time on the USQ campus, to allow them to view the results of this project. This allows the public to make up their own mind on the level of EM radiation in the area and allows a much more aware public to make an informed discission.

Consequences of this project could be quite varied, from criminal acts being discovered to a safe, highly efficient EM environment providing minimal electromagnetic radiation to the public. The results of this project also have the ability to allow many other similar projects to be undertaken in other areas around out country. It may also raise more questions as to the effects of the radiation that are present from both a health standpoint, as well as an engineering view of whether it can be improved further.

Being based on a public concern this dissertation has the possibility to be a highly important document, if the results bring up concerns about the world. For this reason this dissertation is to be treated as if it may fall under public scrutiny at any time in the future. The results of this research should be made public to any who wish to view it, allowing them to weight up the consequences of this dissertation.

2.7.4 Engineers Australia: Code of Ethics

The engineering main codes of ethics are:

**to respect the inherent dignity of the individual*
**to act on the basis of a well informed conscience*
**to act in the interest of the community and to uphold its Tenets.*
(The Institute of Engineers, Australia, 2000)

The Tenets of the Code of Ethics are:

1. members shall at all times place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests, or to other members;
2. members shall act in order to merit the trust of the community and membership in the honour, integrity and dignity of the members and the profession;
3. members shall offer services, or advise on or undertake engineering assignments, only in areas of their competence and shall practise in a careful and diligent manner;
4. members shall act with fairness, honesty and in good faith towards all in the community, including clients, employers and colleagues;
5. members shall apply their skill and knowledge in the interest of their employer or client for whom they shall act as faithful agents or advisers, without compromising the welfare, health and safety of the community;
6. members shall take all reasonable steps to inform themselves, their clients and employers and the community of the social and environmental consequences of the actions and projects in which they are involved;
7. members shall express opinions, make statements or give evidence with fairness and honesty and on the basis of adequate knowledge;
8. members shall continue to develop relevant knowledge, skill and expertise throughout their careers and shall actively assist and encourage those under their direction to do likewise;
9. members shall not assist, induce or be involved in a breach of these Tenets and shall support those who seek to uphold them.
(Institute of Engineers Australia, 2000)

The format of the USQ project subject allows the students to meet all of these tenets. For example in this project it is required to research current knowledge and standards then perform measurements of electromagnetic radiation within public. Analysis of the risks should be completed and comparisons between results and the current standards should be made, allowing the potential of public concern to be discovered.

All of this must be done with honesty to the community and the knowledge acquired should be kept up to date as the project progresses. The basis of this project is itself a public awareness of the concerns surrounding the issue of electromagnetic radiation and so this project is in direct support of the community in this regard. Using the standards set by the authorities it is possible to have an excellent guideline which is able to show the best way to follow these tenets and the Engineer Australia code of ethics.

2.7.5 Safety Analysis

There are a few safety issues that can be associated with the project that has been undertaken. The hazards that are needed to be aware of during experimentation and project design are listed here with possible precautions and likelihood of happening. To weight up the significance of each of these situations it is required have to identify the hazard, what is the cause of the danger, and weigh up the risk which is both the likelihood and severity of the outcome of exposure to the hazard.

2.7.5.1 Electrical Exposure

When working with electrical equipment electrical exposure is always a safety hazard. In this case with a live battery source, which may involve two, in-parallel car batteries, there is the possible likelihood that electrical shock or burning could occur due to high currents. Also with these car batteries being linked to a 240V sine wave inverter the risks are slightly increased. This is an increase through the use of the 240V ac in an outdoor setting where the risk of contact with the ground is increased and potential risk of electrical is enhanced if any external causes allow for an exposure to the 240V AC.

A precaution is to have all equipment insulated is necessary. Already the inverter, antenna cables, spectrum analyser and all associated links are shielded. The part with the least shielding is the car battery itself. Minimal involvement with the car battery should occur to minimise this risk, and due caution should observed when battery is required to be used.

The outcome of this safety hazard should be minimal. A burn is the most likely occurrence in this case. This will be unpleasant but not fatal. The currents that will be worked with are significant enough to cause a problem if a shock occurs in the right place on the body but this is highly unlikely. This could only occur from negligence in the project methodology.

2.7.5.2 Acid Exposure

A large risk is the risk of Car Battery acid exposure. This can occur if the batteries are tipped, dropped, knocked, etc. The likelihood of this occurring is very small if due caution is observed. The highest risk is during transportation of the batteries, in a car or on a trolley. Careful handling of the batteries leads to a small likelihood.

Precautions for the batteries are as follows. They are to be kept, at all times, on the provided trolley or stored safely for moving (in a car). They are to be secured correctly when moved so they are unable to fall over. When carried or moved they are to be moved as slowly as is practical to minimise bumps or careless rushing. When set up to be used on site they should be kept separate from the other equipment to avoid acid burning leading to unsafe equipment. They should also not need to be touched while testing occurs.

The outcome of this hazard is an acid burn of various degrees. A small acid spill may cause a small burn over a small area and should be washed immediately and a medical staff consulted at the soonest, safest convenience. Negligence of the guidelines given above could lead to a large spill. This could lead to a large burn, over a large area of the body, with the potential to risk others. This should not occur but one precaution for this hazard should be to take a bottle of water on site to wash away any acid exposure as quickly as possible.

2.7.5.3 Cuts, Scrapes, Drops and Accidents

These hazards are present in many situations. Due to the use of large components, drops may occur as well as trips, falls, stumbles or cuts on metallic equipment. The risk of this is slight but may occur.

Precautions once again are care and covered clothing, footwear. The result of this hazard is only minimal with only small injuries occurring. While these pose no real danger it must be noted that they may occur and precautions should be used to reduce the risk. If a large Item is dropped it may land on a foot causing serious damage but this would only be caused by negligence in transportation.

2.7.5.4 Electromagnetic Radiation Exposure

As this project is dealing with electromagnetic radiation exposure and the associated health risks it is required that awareness of all risks which may occur from electromagnetic exposure. There should not have to be exposure to any electromagnetic radiation that is above the safe levels associated with the communications or electrical standards. Some time will be spent exposed to various signals but this can be minimised.

The likelihood of radiation exposure is certain. The risk of being exposed to a level of electromagnetic radiation above the safety standards is highly unlikely. The experiment will not add any extra danger to the area in the way that it is performed and the exposure levels encountered will be the same as any the public could encounter.

Precautions for the exposure to higher than standard levels of radiation is to minimise the exposure as much as possible. The job should be done as efficiently as is needed and exposure to the source cut off or minimised as soon as possible.

If at any time it is found that the levels of radiation are above standard immediate isolation from the source and a risk assessment should be conducted as soon as possible as to the level of this risk and outcome of exposure. If it is deemed to still be relatively safe the measurement is to be finished as quickly as possible. This can be important to provide authorities with information on the situation.

If it is deemed too dangerous immediate evacuation from the site should occur. If any measurements are found to be above the standards the relevant authorities should be immediately notified and provided with as much data as possible.

The outcomes of this exposure are varied and inconclusive. Any health risk that has been raised in the conduction of this project is to be assessed individually.

2.7.5.5 Ergonomic stresses

This is the result of spending a long time at desks, sitting positions, etc. Bad posture, difficult bending and many other things lead to aches, pains and developing muscle problems. This is quite possible to occur if a long time is spend at the computer or building circuits for this project. Also lifting and carrying strains may occur.

Precautions are to plan to take a break every hour roughly in which you move around, stretch and do some physical movement. This hazard can manifest as small aches or stiffness or can lead to long-term back problems. Lifting should be conducted with the legs, allowing for a straight back for support.

Chapter 3 – Experimental Methodology

3.1 Experiment Preparation

Preparation for the experiment involved research into the types of equipment to be used, suitable site locations, the nearby signal sources, accessibility to sites and also giving consideration to expectations and testing methods. A trial day was also held where the equipment was set up at the University for testing.

3.1.1 Equipment

The equipment was organised through David Parsons and Terry Byrne. The choices of equipment were influenced by resources available to USQ. Buying new, mostly expensive, equipment was not an option due to the small budget allowance allocated to the project.

What was readily available was a spectrum analyser, a computer with the relevant spectrum analyser software, a 30MHz to 800MHz biconical antenna, a 30MHz to 1GHz Ultralog antenna, a small dipole antenna and a wire loop. Also all the required connections were available. This was all that was required to take initial readings.

It was determined that the equipment needed to be portable. This required a portable power source, as the equipment was operating on mains power at the time, which was purchased by the university. Two deep cycle batteries were obtained and used for this function. If required, a car battery was also available. Using battery power also required the use of a DC to AC inverter. This was also available through the university and produced the required 230V AC power source available. The deep cycle batteries provided two hours of safe power, which could be pushed to two and a half if essential.

The antennas that were available would limit the spectrum range. Analysis of the antenna revealed there was a 30MHz to 1GHz Ultralog which had been fully calibrated and a 30MHz to 800MHz Biconical which was calibrated with respect to the Ultralog. Since it covered the same range and was calibrated using the calibrations of another antenna it was decided not to use the Biconical.

A higher frequency range was wanted to see the 1GHz to 2GHz mobile frequencies. The dipole was equipped to cover this range but with no calibration it could not be used for accurate results. However, it was used/had sufficient capability to see where some peaks from 1GHz to 2GHz were found.

The final pieces of equipment gathered were two trolleys. One was used for the large Ultralog antenna, and the second contained the computer, power, spectrum analyser, and all connections and accessories needed for the computer. These were necessary for the ease in transporting all other equipment and were exceedingly helpful for all on-campus locations.

3.1.1.1 Rohde & Schwarz – HL562 Ultralog Antenna

(Rohde and Schwarz, 2004, online resource)

The Ultralog antenna is rated to cover the 30MHz to 3GHz. Unfortunately the calibration was provided from 30MHz to 1GHz, and so is only reliable in this range. The extra range could be used to find peaks from 1GHz to 3GHz, but without accurate amplitudes. This range was unknown at the time of use, with statistics from the provider indicating it was only capable of 30MHz to 1GHz.

Also the uncalibrated measurements were taken from 1GHz to 2GHz using the university's dipole antenna. So it was decided that further testing would not happen as the benefits of this new discovery would only provide uncelebrated amplitudes from 2GHz to 3GHz, per locations, and these values would not be accurate amplitudes. As well as this, to take the antenna around to each location would be very timely and require a lot of re-organisation. So for little benefit it would require a lot of time to remeasure the 2GHz to 3GHz range.

The Ultralog is designed to combine the characteristics of a Biconical antenna with a log-periodical antenna.

Input Impedance - 50Ω
Gains (Above 200MHz) – 8dB
Maximum Input Power Range – 150W to 500W
Temperature Range – 0ºC to 40ºC
Dimensions (W x H x L) – Approx 0.6m x 1.65m x 1.68m
Weight – Approx 5kg

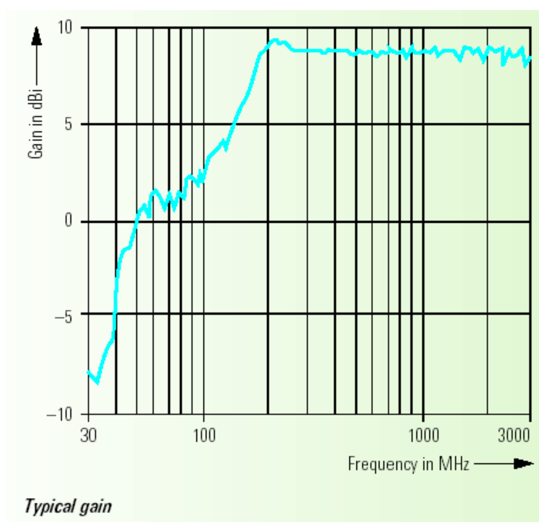

Figure 3.1: 30MHz to 3GHz Gain Characteristics for the HL562 Ultralog antenna (Rohde and Schwarz, 2004, online resource)

Figure 3.2: Picture showing the HL562 Ultralog Antenna (Rohde and Schwarz, 2004, online resource)

3.1.1.2 Rohde & Schwarz – ESPI 7 Test Receiver

(Rohde and Schwarz, 2005, online resource)

Frequency Range – 9kHz to 7GHz
Frequency Resolution – 0.01Hz
Display Resolution – 0.1Hz
Measurement time per frequency - 100μs to 100s (selectable)
Scan Traces – Max Peak, Quasi-Peak and Average
Temperature Range - 0ºC to 45ºC
Amplitude Error (based on 128MHz and -30dB signal) - <0.2dB
Frequency Error – (frequency x reference error + 0.5% x span + 10% x resolution bandwidth + ½ (last digit))

This test receiver/spectrum analyser was provided by the university. It is a fully automated test receiver which is linked by GPIB cable to the computer. This allows the receiver to be fully controlled by the computer software, and to allow all measurements to be automatically logged by the computer.

Figure 3.3: Picture showing the ESPI Test Receiver (Rohde and Schwarz, 2005, online resource)

All software was previously loaded onto the computer, with the calibration for the Ultralog and Biconical antenna already complete. This meant all that was required was to adjust the settings to take the right measurements, over the right frequencies, with the right time, bandwidth and scan types. All this was prepared on the practice day, and then was easily applied to the real testing week.

There were a number of benefits and disadvantages to the software/test receiver package.

The benefits were that it was an easy way to log a large amount of data, relatively quickly. Without this computer setup this experimentation would have been insufficient and provided very few useful results. Also since it was already purchased and used by the university a lot of the preliminary information was set up, such as the calibration. This allowed for many tasks to be skipped which could have taken a long time and may have caused difficulties, slowing down the progress of the project.

A few minor problems could be foreseen as disadvantages. Occasionally the test receiver would lock up. The only way to overcome this problem was to reboot the system each time, delaying testing by up to 5 minutes. When running off battery power this could be a significant amount of time, leading to the batteries to drain before testing is completed.

More modern software would have increased the speed of the measurements. The older software used also lacked functions available in the modern softwares. These functions then had to be performed manually which also took more time. For each measurement the program required a scan to be run. Once this scan was complete a screen shot needed to be taken of the graph and pasted into MS Paint and saved as a .JPG file.

The data had to be printed to file, which saved it as an .RTF format, or a rich text file. This also could not have a file name sting of longer than 8 characters. This was required to be done for each test, and three times, once for each different scan type. This was where all the time was spent and so in one hour it was often only about 10 to 15 minutes worth of actual testing.

Then for the data analysis the software also provided some inconveniences. The data being in rich text format contained unwanted information within the file and had to be imported each set of data singularly, which was about 540 sets in total, separately into excel and then transfer them into one larger, useful document. With the graphs also being stored as print screens in jpg format they also need to be cropped down when they want to be used.

All this was required just to get the data and graphs into a useful format, and was the main way in which the software was a disadvantage. This would have all been fixed with newer software if it was available.

3.1.2 Location Details

Objectives regarding locations of the experiments included deciding on the number of test sites, the location of test sites and justifying why each site was chosen. The locations were chosen according to specific criteria which are/will be outlined below.

Firstly what exposures would be a major influence for these measurements? It was decided focus would be aimed at FM radio, mobile phones and electronics leakage. USQ has an FM antenna on the roof of S-block and so a worst case scenario test was set up on fifth floor S-block to see the strength of this antenna. The highest concentration of mobile phone sources was found in the Refect during lunch hours so a test during this time would be required. Lastly for electronics leakage, the largest concentration of this would be in either an office/admin area of the university or the computer labs. It was decided that having access to the fourth floor admin area in Z block would have the highest levels of electronics leakage that was required for this experiment.

After these four typical situations for university were used as three more locations. One was a lecture theatre, as students spend many hours each day populating these areas, the quadrangle as this is the main outdoor area, out on the oval near Z block and finally in a Z block lab.

All of these are areas that are often populated by students and teachers at different times of the day and have different external EM radiation sources nearby. This provided two indoor and two outdoor situations as well. The USQ locations can be seen on the map provided in Figure 3.4.

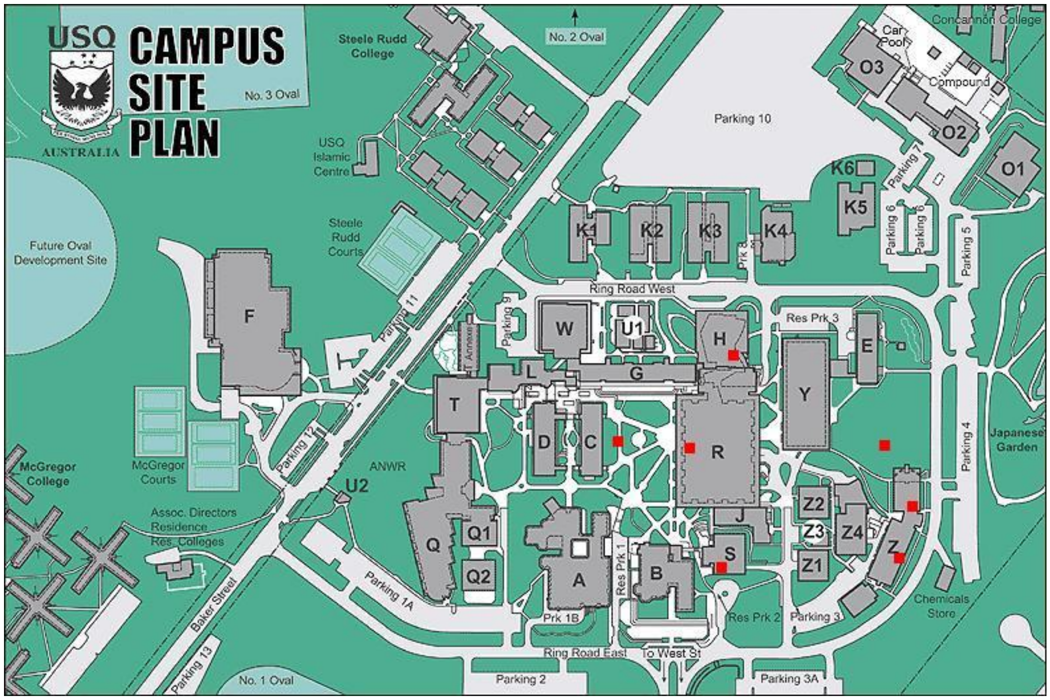

Figure 3.4: Map showing the on-campus measurement locations (University of Southern Queensland, online resource)

The final two locations chosen were outside of USQ. One was a mobile phone tower to the west of USQ which also provided a few other services. The other was at a park outside of USQ chosen to see the difference between an outdoor location at USQ and an outdoor location closer to the city on public property.

Figure 3.5: Photos of four testing locations. Clockwise from top-left is H Block Lecture Hall, S Block 5th floor, Z Block Laboratory, GSM Transmission Antenna.

Another location, being situated at the television broadcasting towers at Mount Lofty in Toowoomba, was also selected but unable to be utilised. Only short trips were able to be made in the car without damaging the equipment and access to the top of the mountain was believed to be difficult with the equipment chosen for this experiment.

The nearby sources, as well as other noticeable influences on any signals, for each location are listed below as follows.

3.1.2.1 Z Block Electronics Laboratory

Site Information: 3rd floor, pointed north.
Long Distance Sources: 102.7 FM radio antenna about 300m behind. Average radio, TV broadcasting signals. Low level mobile phone signals.
Short Distance Sources: Air Conditioning off, lights off, some nearby electronics used in electrical courses.
Other factors: Anechoic chambers in next room.

3.1.2.2 Z Block Administration Offices

Site Information: 4th floor, pointed west.
Long Distance Sources: 102.7 FM radio antenna 300m perpendicular. Average radio, TV broadcasting signals. Low level mobile base signals.
Short Distance Sources: Air Conditioning on, lights on, large amounts of nearby electronics as used in an office such as computers, photocopiers, etc. Medium level mobile handsets.
Other Factors: Human movement around site..

3.1.2.3 H Block Lecture Hall

Site Information: Top of Alison Dickson Lecture theatre (H108), pointed North.
Long Distance Sources: 102.7 FM radio antenna 300m perpendicular. Lower radio, TV broadcasting signals. Low level mobile base signals.
Short Distance Sources: Air Condition on, Lights on, no nearby electronics, low level mobile handsets.

3.1.2.4 Z Block Oval

Site Information: 20m from building, pointed north.
Long Distance Sources: 102.7 FM radio antenna 300m behind. Average Radio, TV broadcasting signals. Medium level mobile base signals.
Short Distance Sources: Outside, no short distance sources.
Other Factors: Low/Medium levels of human movement around site.

3.1.2.5 The Quadrangle

Site Information: 5m from building, pointed north at FM antenna.
Long Distance Sources: 102.7 FM radio antenna 100m in front. Average Radio, TV, Broadcasting signals. Medium level mobile base signals.
Short Distance Sources: Outside, Medium level mobile handset signals, no electronics or lighting, but nearby buildings.
Other Factors: Medium levels of human traffic around site.

3.1.2.6 S Block 5th Floor Foyer

Site Information: 5th floor, point at 102.7 FM radio antenna less than 10m away
Long Distance Sources: Average Radio, TV broadcasting signals, medium level mobile base signals.
Short Distance Sources: 102.7 FM radio antenna <10m away in front. Air Conditioning on, Lights on, nearby lifts, low level human traffic, no other nearby electronics, transmitter room less than 5m away.

3.1.2.7 The Refect

Site Information: Ground floor pointed north.
Long Distance Sources: 102.7 FM radio antenna 100m away perpendicular. Average Radio, TV Broadcasting signals, medium level mobile base signals.
Short Distance Sources: Very High level of mobile phone handsets. Air Conditioning on, lights on, nearby electronics such as TV's, cooking appliances, refrigeration.
Other Influences: Very Heavy nearby traffic.

3.1.2.8 GSM Mobile Transmission Antenna

Site Information: Side of road pointed north at nearby transmitter 100m away.
Long Distance Sources: Average Radio, TV Broadcasting signals, medium level mobile base signals.
Short Distance Sources: GSM and other signal transmitter 100m away. Outside. No nearby electronics.
Other Influences: Low level of car traffic.

3.1.2.9 Public Park

Site Information: In park on the way towards downtown Toowoomba.
Long Distance Sources: Slightly higher than average Radio, TV broadcasting signals, slightly higher than average mobile base signals.
Short Distance Sources: Almost none. No electronics or mobiles. Outside.
Other influences: Medium level car traffic greater than 100m away.

3.1.3 Testing Methods and Location Confines

The sites that were chosen, and those that were not, were based on a few reasons. There were a number of office areas in USQ, as well as lecture theatres but what was chosen was due to the accessibility of each site. Z block offices were of use as the engineering administration staff are always helpful for project related problems. The lecture theatre was both one of the biggest ones and was available at the time required.

All off campus locations were within short driving distance and in accessible locations. S block was the least accessible of the final sites chosen but it was felt that since the FM antenna was on the S Block roof, it was required to take a worst case scenario test from as close as possible. This would alleviate concerns with the public that being in S block was in any way an issue.

The testing methods for these sites were all the same. If possible it was required to do four 30MHz to 1GHz scans, both with a horizontal and vertical orientation. Two extra 600MHz to 1GHz scans, and two extra

30MHz to 250MHz scans, both with vertical and horizontal orientations. As well as this two dipole scans were conducted from 600MHz to 2GHz. This seemed sufficient to provide enough data (eight large scans, 8 smaller range scans, and two dipole scans) for each site. The completion time took just under an hour, without interruptions, allowing for two scans a day to be conducted on the safe battery life of around two hours.

If space was a concern scans could be cut down and the need to only complete a horizontal or a vertical scan would cause no problem. This was dependant on each site and situation. For the locations that were outside USQ, the scans were only able to be horizontal, as to fit the antenna in the car the stand for the antenna had to be removed and a temporary stand rigged up in the back of the car, using a weight to hold the antenna in place.

The USQ offices did not allow for as many scans as it was a very busy place with very little room. Due to the working environment scans were kept to a minimum and the measurements finished as quickly as possible. For the Refect, two extra dipole scans were conducted, as mobile phones were a major influence for this site.

3.1.4 Test Day

One day was used in advance as a test day. The purpose of this day was to test that all equipment worked and to help with familiarisation with the equipment and testing process. It also helped in the development of the methodology.

The test day consisted of connecting up all equipment on mains and testing that each piece worked separately as required. Then they were all connected together to check the whole system was operational. The Spectrum Analyser required information from the antenna, and needed to pass along information to the computer, which required the spectrum analyser software to be calibrated, receive a signal and log the right data.

Required checks included analysis of the software to make sure that it was ready for testing, how to change scans, how to alter antenna and antenna options, how to record the data and export it. With only a few minor setbacks this was all successful. The last part of the test day was to test the battery power supply and functionality. At the time only car batteries were available so the DC to AC inverter was used, in conjunction with the batteries, to provide AC power to the equipment. This was successful and lasted for 3 hours before concerns for the batteries arose.

3.2 Experimentation

3.2.1 Experimentation Discussion

The next stage of the project involved the experimentation. The experimentation involved physically going into the field to acquire data. The methodology for this has already been covered in many previous sections and so shall give a brief discussion here on the plan for the experimentation organisation itself.

3.2.1.1 Day One

The experimentation was planned to take place over a five day period. This period was planned to be sufficient time to produce scans on around seven to eleven possible sites. A lot of the organisation for the experimentation had to wait until the week itself as organisational problems would occur during the testing week.

The first day of the week was required to set up all equipment and make sure it all worked. Battery testing was important to finish for this day as it was a requirement to know how much they could handle without damaging the batteries.

The batteries were tested for two and a half hours and this was fine. When the batteries were set to charge it was confirmed that this was a near the maximum that they should be discharged in a single session.

Also during the first day it was required to test that none of the settings had changed within the software and that the hardware and software were all communicating properly with no errors. Also the trolleys were acquired and set up to allow for transportation of the equipment.

Finally some initial testing and exporting of data was completed to see how the software exported data, which tools were needed and if they were sufficient.

3.2.1.2 Day Two

Day two consisted on testing on campus. Three sites were tested including the Z Block Laboratory, the H Block Lecture Hall and the Z Block Administration Office.

The first test was the Z Block Laboratory as this required no movement of equipment and was used to test how long a complete series of tests would take. A full session of testing turned out to be around one hour and five minutes at a relaxed pace which meant that two tests could be completed using the batteries each day.

The next testing site was the Z Block Administration Office which was booked in and confirmed with the administration officers for 1:00pm. This testing site had limited space as the antenna was required to be set up in a walkway, with the computer trolley also set up in a separate walkway. The experimentation was shortened with less scans being completed as this potentially could have caused a safety risk with large amounts of walk through traffic.

The last testing site, in the H Block Lecture Theatre was booked in for 4:00pm. This site was available for the rest of the day so there were no difficulties with this site. There was plenty of space and testing was relatively simple.

3.2.1.3 Day Three

Day three consisted of two outdoors, on-campus sites. The first of these was the Z Block Oval. This was conducted in the morning with no concerns. The batteries were required for this testing.

The second site was the Quadrangle in the centre of the University. This was conducted at around 11:30pm, allowing for people to arrive for lunch during the last half an hour in the hope of some more mobile phone signals to be present. This site also required the batteries to be used and so that was the two outdoors sites available for that day.

3.2.1.4 Day Four

The fourth day consisted of two indoors locations. The first was the S Block 5th Floor Foyer. This was booked in with nearby staff for the early morning as a safe time to complete this testing.

There were complications with the S Block location as the entrance ramps were very narrow and windy. There was little room in the lift and the antenna had to be transported up the lift in pieces. In the end this only caused minor hassles as all equipment was able to be relocated on the fifth floor.

Once set up on the fifth floor the testing was very simple with no concerns. The batteries were required as the area in which the testing was completed had no mains power access. The same problems occurred on leaving the site that were present when entering the site and it was once again a difficult take to move all the equipment out of the location.

The second location for the fourth day was the Refect. This site was booked in with the Refect staff for 12:00 noon. This allowed for the maximum number of people to be present, allowing for the largest amount of mobile phone signals. There were no difficulties with this except the random nature of people coming and going, so it was hard to determine if this was a typical day at the Refect. Once again there was no mains power access so batteries were required for this site as well.

3.2.1.5 Day Five

Day five involved the two off-campus locations. These were the most difficult locations as the equipment had to be loaded into the car and transported. The antenna stands could not be fit into the car, and the antenna itself only just fit. This meant that the off-campus locations required me to rig up an antenna stand which was isolated and stable. This was done using a counterweight and the back of the car, but this only allowed a horizontal orientation to be used due to the vertical orientation touching the ground.

The first site was the GSM Transmission Antenna site. The antenna was set up along the side of the road, as it was a low-traffic road almost out of town. Other than the limitations of having no trolleys to hold the equipment there weren't any other concerns which arose with this testing.

The second site was the public park site. The same problems that were faced at the GSM Transmission Antenna site were also found here with no trolleys or antenna stand able to be used. The equipment was set up at a park table and the antenna once again set up out of the back of the car.

One idea was to test the TV broadcasting sites for Toowoomba on the fifth day as well but there were too many limitations.

The location was at least twenty to thirty minutes driving away and without a stable stand any bumps may have damaged the equipment so the speed of the car would have to be limited.

Also the TV Broadcasting are up on a hill with limited car access which made transportation without trolleys to be very difficult and the battery life was also running close to its limit. These were the reasons for not taking measurements for the television antennas.

3.2.2 Further Experimentation

Further experimentation was going to be conducted in a few conditions.

**The current measurements were discovered to be faulty or inaccurate.*
**There was a development in the technology which allowed for an increase in measurement range.*
**Further sites were discovered which would bring a sufficient level of extra information to the project.*
**New testing methods or ideas were discovered which would increase knowledge sufficiently towards the project.*

None of these occurred until near the end of project when it was believed that recalibration of the Ultralog could lead to full 30MHz to 3GHz scans. However this information arrived too late to put into effect and so is recommended for future studies.

The results which were measured have not yet been found to be inaccurate and no further testing was required for this experimentation. Further discussions on this issue will be completed later in Chapter 4 (page 75).

3.3 Implementation

3.3.1 Implementation Discussion

The implementation is the final part of the experimentation process. This involves the analysis of the measured scans to produce some usable data and information.

The first part of this was to turn the scans into useful results. This was discussed in the disadvantages section of the Test Receiver, in (Section 3.1.1.2, page 55). The old technology did not allow for easy recording of results. The graphs required to be print-screened and then trimmed down. Also the data results were required to be imported singularly to excel and the copied into a worksheet containing the other data.

The desired results for this implementation were to compare our values with the current Australian standards. This is the number one concern as it may reveal how close or far scans are from these restricting values.

Once this comparison is completed then comparisons between the different sites should be finished.

A number of key points are;

*comparisons between signal amplitude for frequencies and sites
*to view the amount of amplitude variation over time for each signal
*to view number of peaks present at each site and how they compare
*comparisons between the different antenna orientations and how it applies to amplitude or the number of signals present
*a view of general trends and patterns which emerge and conclusions which can be drawn from these

This is a few of the implementation techniques which were used with more determined as the results were calculated. This was because with such large amounts of data it was hard to initially determine which methods could be utilised and which ones would be optimal.

3.3.2 Calculations and Scientific Theory

For the implementation to take place it was needed to look at the calculations which are required to take place. The final values should be either one of the following two units.

3.3.2.1 SAR measured in W/kg.

The formula for SAR is:

$$SAR = (\sigma |E|^2) / \rho$$

E is the Field Strength and is V/m
σ is the conductivity of the medium (in this case tissue) and is $\Omega^{-1}m^{-1}$
ρ is the mass density of the medium (Tissue) and is kg/m^3

It is possible to find estimations for the conductivity and mass density but unfortunately the calculation of SAR itself requires complex mathematics, such as Finite Difference Time Domain calculations and in the real world application uses complex maths programs to work out the SAR mapping. For more information on this please look in (Section 3.3.2.4, page 70) for discussion on SAR calculation. In this project it is not possible to find the time to calculate SAR values and would not be able to accurately estimate the value.

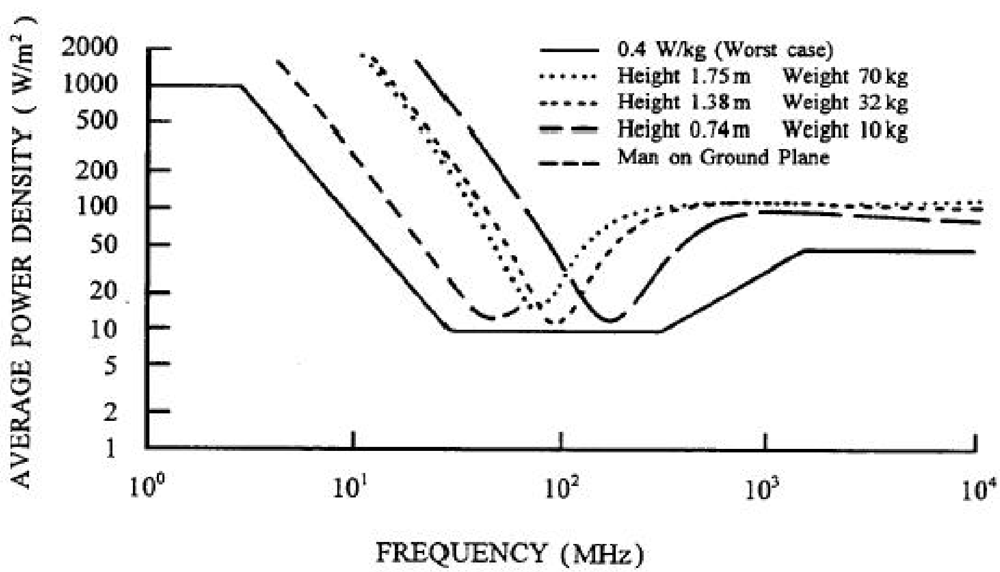

FIGURE A1 POWER DENSITIES THAT LIMIT HUMAN WHOLE-BODY SAR TO 0.4 W/kg
(From Radiofrequency radiation dosimetry handbook(Fourth edition))

Figure 3.6: Measured Power Densities which equates to the whole-body SAR limit of 0.4W/kg (Standards Australia, 1990)

The graph shown above contains SAR estimations dependant on human heights and weights. It was obtained from AS2772.1 (Standards Australia, 1990). As can be seen the full body SAR changes significantly for different body weights and also the frequency of the EM radiation also has significant effects. From the graph estimations can be made on the effect of full body EM exposure but this cannot be confirmed through calculations.

SAR limits are used in a number of standards. The main one is a mobile phone handset which can only have 2W/kg when measured in a 10g area.

3.3.2.2 Power Density in W/ m^2

The measurement of power density is relatively self explanatory. It is the density of an electromagnetic field's strength. (ETS Test Systems, LP, 2001)

The Formula for Power Density is $Pd = E^2 / 120\,\pi$

Where E = Field Strength in V/m

As can be seen Power Density can be directly calculated from the field strength in V/m.

Power Density is the standards involved in many station antennas. For example a 3G base station has a limit of $10W/m^2$ public exposure limit.

3.3.2.3 Field Strength in V/m

It can be seen above both final results are dependant on Field Strength, measured in V/m. So calculations of field strength are required to be able to reach the final outcome.

The field strength calculations are relatively simple. The output of the spectrum analyser is in V/m and only requires a calibration mapping for the desired antenna that is to be used. The mapping for the antenna has already been calculated and is in essence a dB loss map over the different frequencies.

The final results that are acquired are in the form of a frequency value on the spectrum analyser is measured in dBμV/m.

To change this to a basic μV/m

Field Strength = $20\log_{10}(FS_{dB})$

This gives the value of V/m that is required and after these further calculations of power density can be found and estimated as a value of SAR.

One note that is a new antenna calibration is required for each new antenna used.

3.3.2.4 Additional SAR Information

Electromagnetic Fields, in close proximity to human tissue, is measured in a different way to longer distanced fields. For example this applies to mobile phones as a main source but also any electronic equipment used on, or around, the body. The measurement that is to be taken is called Specific Absorption Rate (SAR).

The units of SAR are Watts per Kilogram (W/Kg) which means watts of power absorbed by a kilogram mass (in this case of human tissue). In basic terms this means the maximum amount of power absorbed by an area of the tissue and the possible outcome of this standard not being adhered to is the heating of tissue.

Measurement of SAR values are reasonably hard to achieve. SAR is calculated using the following formula.

$$SAR = \frac{\sigma |E|^2}{\rho}$$

Where σ is the conductivity (Ω-1 m-1) of the tissue
ρ is the mass density of the tissue (kg/m3)
E is the electric field strength (V/m) (reference)

From the formula above the required values to calculate SAR are the tissue mass density and conductivity which are both extremely complex to simulate in a human body with different tissue structures and shapes.

This testing and calculation of SAR values at the Telstra research laboratories is carried out using a Phantom head or body which recreates the characteristics of human tissue (Carratelli, McIntosh and McKenzie, 2002). This uses liquids which have the conductivity and density characteristic of our different tissues and these can be used to accurately represent a human for testing purposes, without the risk of exposure to a living being. This can be seen in the picture below.

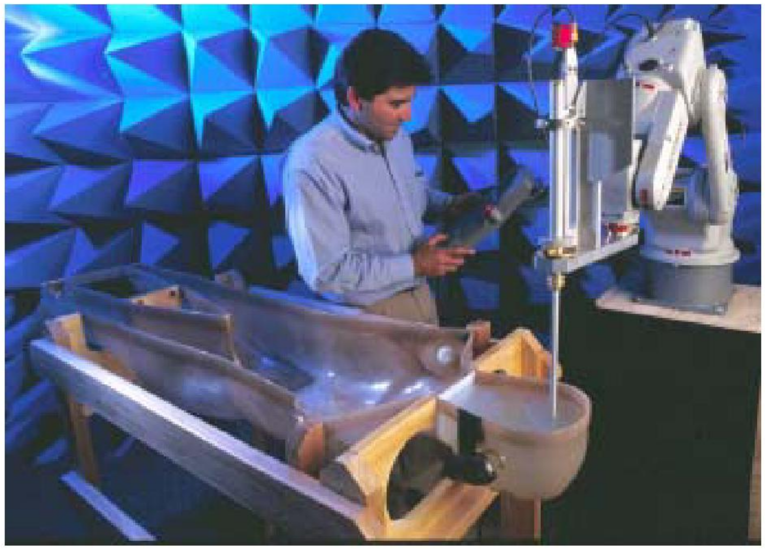

Figure 1. The SAR Robot Measurement System at TRL

Figure 3.7: The SAR Robot Measurement System at the Telstra Research Laboratories (Carratelli, McIntosh and McKenzie, 2002)

Using a mesh representation of the head (for example) to break the head into minute mathematical parts, Telstra uses the Finite Difference Time Domain theory in complex mathematical software to solve the EM exposure of these phantom heads and bodies and are then able to represent the exposure that would occur in a real life situation for the tested products. A cross-section image of a human head is also used in another method to show the different tissue characteristics of bone and cartilage and this is used in the recreation and mathematical modelling of the EM exposure. These characteristics are shown in Table 3.1.

Table 3.1: Properties of different tissues within the Human Head (Carratelli, McIntosh and McKenzie, 2002)

Table 2. Head Tissue Properties (electrical properties for 900 MHz)

tissue	conductivity ($\Omega^{-1}m^{-1}$)	relative permittivity	mass density (kg/m^3)
cartilage	0.782	42.65	1000
muscle	0.969	55.95	1050
eye	1.900	70.00	1000
brain & nerve	0.766	45.80	1050
dry skin	0.867	41.40	1000
blood	1.180	62.00	1000
skull	0.242	16.62	1850

Note: these values are the set values given in the XFDTD package and may differ from those in [7, 8].

From all this information the end result that is produced can be seen in the images below.

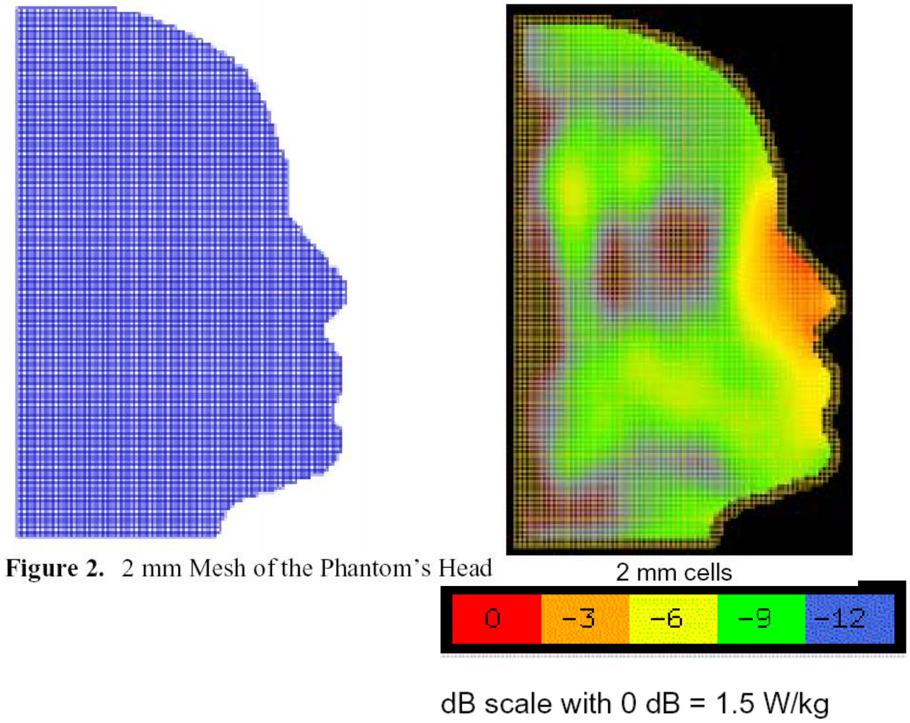

Figure 3.8: 2mm Mesh of phantom head with measured results shown on the right. (Carratelli, McIntosh and McKenzie, 2002)

The image on the left shows the mathematical mesh of the head and the right shows the final calculated Phantom head's EM exposure.

This is one method of calculating the SAR that is used by Telstra in their laboratories. This is quite an advanced method. Estimations can be made with the right information but when a product is tested to a standard the highest level of accuracy is required.

3.3.3 Expected Results

One area of concern is to the expected amplitude of the results. The most accurate way to verify what the results should be is to compare it to similar testing.

One other experiment has been conducted that was found and was able to provide results for comparison. This was a Mobile Phone base station survey conducted by ARPANSA. This survey looked at a number of possible 'problem base stations' where there was concern by the local community or council as to the safety of the base stations.

Experimentation was conducted to find the highest values of exposure in the general area and the results from this can be shown below in Table 3.2 and Figure 3.9.

Table 3.2: Results of Mobile Phone Base Station Survey 2007-2008 showing the percent of the measured worst amplitude to the standards (Australian Radiation Protection and Nuclear Safety Agency, 2008, online resource)

Suburb/Town	**Address**	**State**	**RF Level (% of exposure limits)**
Bathurst	230 Howick Street	NSW	<0.001%
Rosemeadow	Lot 1 Appin Road	NSW	0.109%
South Coogee	175 Malabar Road	NSW	1.163%
Bli Bli	Whitecross Road	QLD	0.026%
Goodwood	147 Goodwood Road	SA	0.132%
Oaklands Park	Warradale Barracks	SA	0.579%
Sandringham	48 Bay Road	VIC	0.505%
Beaconsfield	20 Moran Street	WA	0.009%
City Beach	Lot 245 Kilpa Court	WA	0.303%

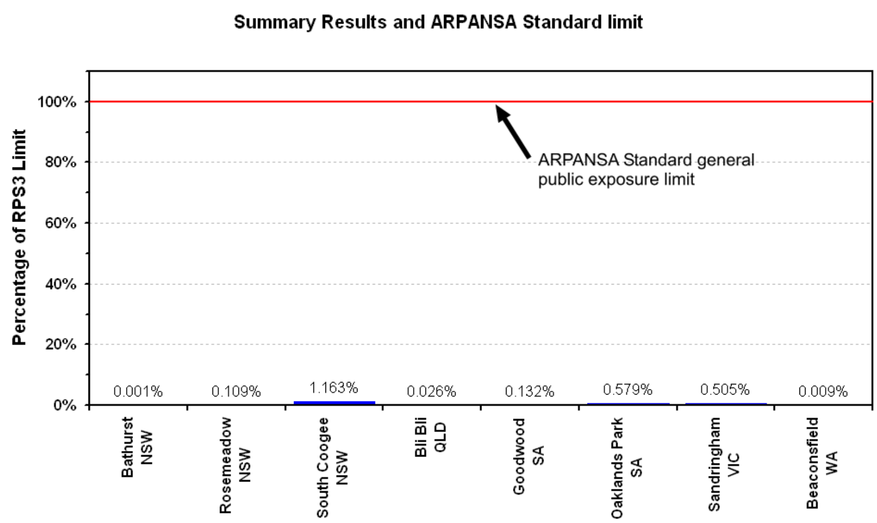

Figure 3.9: A graphical representation of the results gathered by ARPANSA of signal strengths during the Mobile Phone Base Station Survey 2007-2008 (Australian Radiation Protection and Nuclear Safety Agency, 2008, online resource)

The standard limits ranged from $4W/m^2$ to $10W/m^2$ depending on the signal frequency and the results were from <0.001% to 1.2% of the limit.

This gives an estimation on what the results from this study may be. The W/m^2 results of the base station study varied in range from $<0.001mW/m^2$ to low levels at around $0.007mW/m^2$ to $4mW/m^2$.

This study gives a real life study on a very similar area to mine and gives values which can be directly compared. This will be of great benefit to this study. (Australian Radiation Protection and Nuclear Safety Agency, 2008, online resource)

Chapter 4 – Results and Results Analysis

4.1 Raw Data

The results from testing can be seen in the file simonPAECH_Measured_Data.xls. Due to the large amount of data logged it cannot be included in this document, and so is provided as a supplementary document on the dissertation CD, called simonPAECH_Measured_Data.xls.

The raw data was provided in two formats. First is the data which was just explained above, and has been compiled in Excel datasheets. A very small example of this is shown here in Table 4.1.

Table 4.1: Scan Data, in raw value format, scanned at the Z Block Laboratory Test Location.

			LAB TEST 30 TO 1G				
	Test 1	Test 2	Test 3	Test 4	Test 9	Test 10	Test 11
	Vertical	Vertical	Vertical	Vertical	Horizontal	Horizontal	Horizontal
FILENAME:	Radiated Ultra MxPk1						
Date:	29/07/2008	29/07/2008	29/07/2008	29/07/2008	29/07/2008	29/07/2008	29/07/2008
Time:	9:56	10:04	10:09	10:15	10:35	10:40	10:44
Frequency	Level	Level	Level	Level	Level	Level	Level
MHz	dBµV/m	dBµV/m	dBµV/m	dBµV/m	dBµV/m	dBµV/m	dBµV/m
30	38.7	38.89	37.85	39.46	39.12	38.21	37.56
30.06	37.62	37.77	37.97	37.91	37.97	37.71	37.83
30.12012	37.96	38.44	37.57	38.51	37.53	38.01	38.19
30.18036	38.17	38.21	37.58	38.27	38.33	38.18	37.26
30.240721	37.87	37.7	38.78	38.61	37.37	37.94	37.59
30.301202	37.96	38.19	38	38.52	37.56	37.77	38.17
30.361805	38.64	37.33	37.98	38.42	38.23	37.98	37.35
30.422528	37.77	37.74	38.94	38.52	37.39	37.85	37.96
30.483373	38.42	38.32	38.24	37.86	37.67	37.36	38.18
30.54434	37.64	38.26	40.17	38.93	37.9	37.42	37.74
30.605429	38.17	37.81	38.08	38.59	37.87	38.4	37.72
30.66664	37.06	37.7	38.18	38.04	37.87	37.3	37.41
30.727973	37.86	37.74	37.8	39.16	37.96	37.92	37.92

The second is in the form of the software generated scan graphs. Some examples of a few of the graphs are provided here below with a brief discussion on each.

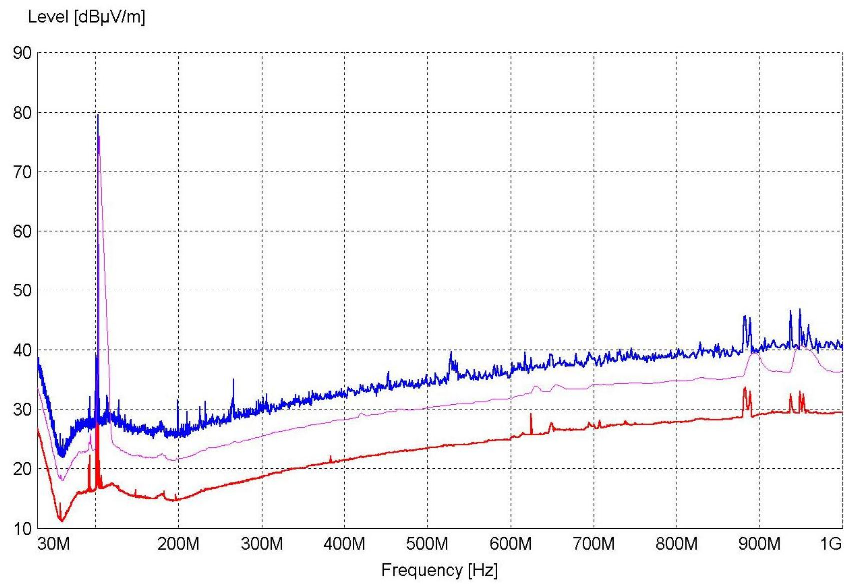

Figure 4.1: Scan Graph showing scan at the Refect, horizontal orientation, between 30MHz and 1GHz.

The example shown in Figure 4.1 is provided as it is a prime example of a scan with little signal activity. There is the signal present at 102.7MHz but that is the only significant peak, with only very small variations in all other frequency ranges.

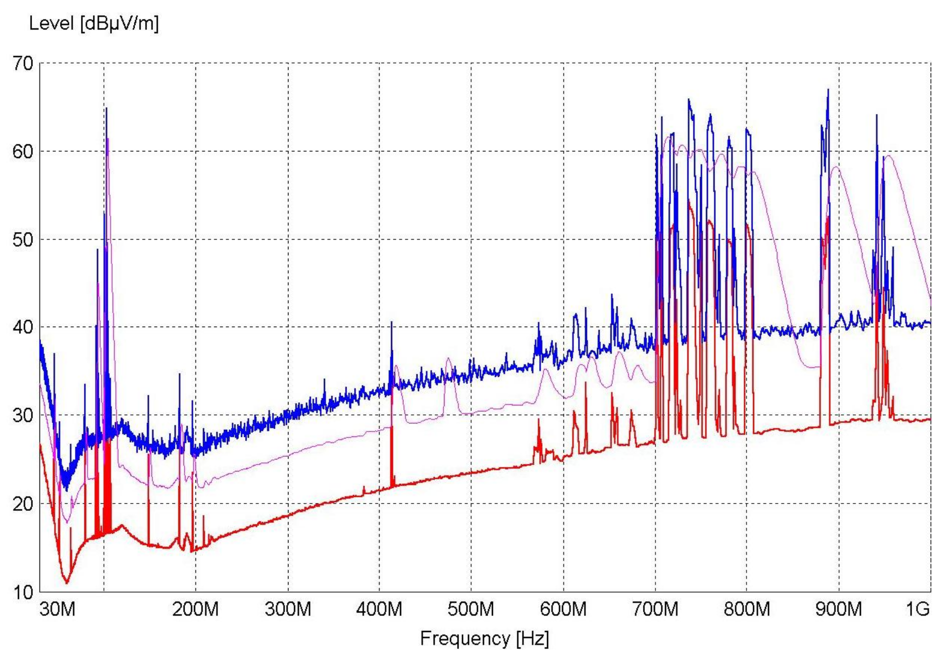

Figure 4.2: Scan Graph showing scan at the Laboratory, horizontal orientation, between 30MHz and 1GHz.

Figure 4.2 is an example of a scan which has significant peaks throughout the 30MHz to 1GHz range. The range between 700MHz to 800MHz is full of significant peaks, at this orientation and the scans at vertical orientation were much smaller at this orientation. This will be discussed in detail later.

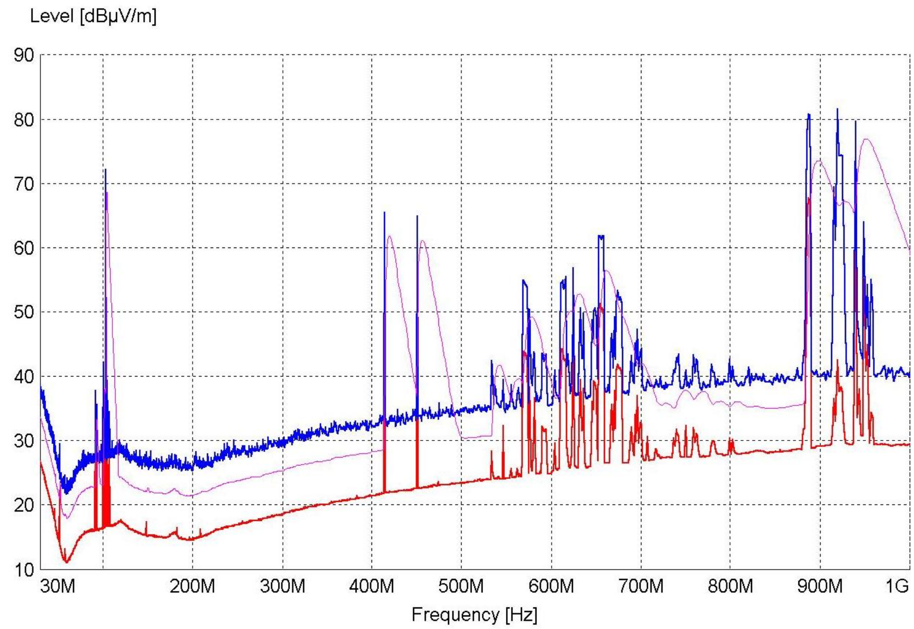

Figure 4.3: Scan Graph showing scan at the GSM transmission site, horizontal orientation, between 30MHz and 1GHz.

This final example is one showing significant peaks through the whole range from 30MHz to 1GHz.

4.1.1 A Note on Scans

The three different colours on the graphs refer to three detectors used by the test receiver to determine amplitudes. These are designed to allow meaningful and comparable measures in a variety of different signal variations such as continuous signals, pulse modulated signals, etc. The blue is a Max Peak test and shows the maximum value. The red is an Average Peak and shows a slightly averaged graph which does not show all peaks and doesn’t show the maximum values. The purple is a Quasi-peak test and shows more signal trends and is averaged even higher.

The only signal which should be taken for the purpose of statistical evaluation is the blue Max Peak test line. The other two are not a true representation, but rather are used to show general trends of the scans.

4.2 Maximum Values

The most important value of the results is the maximum signal value. This determines whether there is any risk of the Electromagnetic radiation exposure having reached the standards restrictions.

The standards, as stated in (Section 2.5.3, page 41), is 0.8W/kg for far-field signals which are the signals which directly apply to this experimentation.

Table 4.2: Table of the 5 largest Scan Values Measured

5 Largest Measured Scan Values				
Test Location	Orientation	Frequency (MHz)	Measured Value (dBμV/m)	Frequency Licensing
Refect	Vertical	910.3107	97.37	Vodaphone CDMA Network
Quadrangle	Horizontal	102.7159	95.86	4DDB Radio
Oval – Z block	Horizontal	102.7159	92.19	4DDB Radio
GSM Transmission Station	Horizontal	923.922	85.49	Black and White Cabs Drayton Rd
S Block 5th Floor	Horizontal	102.7159	84.94	4DDB Radio

Table 4.3: Table of the 5 Largest Frequency Scan Values Measured

5 Largest Measured Scan for Differing Frequencies				
Test Location	Orientation	Frequency (MHz)	Measured Value (dBμV/m)	Frequency Licensing
Refect	Vertical	910.3107	97.37	Vodaphone CDMA Network
Quadrangle	Horizontal	102.7159	95.86	4DDB Radio
GSM Transmission Station	Horizontal	923.922	85.49	Black and White Cabs Drayton Rd
Refect	Vertical	904.8706	83.4	Optus Mobile Network
GSM Transmission Station	Horizontal	888.7446	82.87	Telstra Mobile Network

4.2.1 Discussion of Maximum Values

Table 4.2, containing the 5 maximum values overall, shows that the most prominent signal out of all test locations comes from the 102.7MHz signal, containing 3 of 5 of the highest values. The other two peaks were in the range of 900MHz to 1GHz. It is easily seen that the 102.7MHz value, being the transmission tower on top of S-block had the largest significance around the university, and was the value most likely to reach the standard restrictions.

Table 4.3, containing the highest valued frequency ranges, shows that, besides the 102.7MHz frequency, the other highest values were from 880MHz to 930MHz. This suggested that these signals have the highest possible peak after the 102.7MHz signal.

4.2.2 Highest Value Compared to the Standards

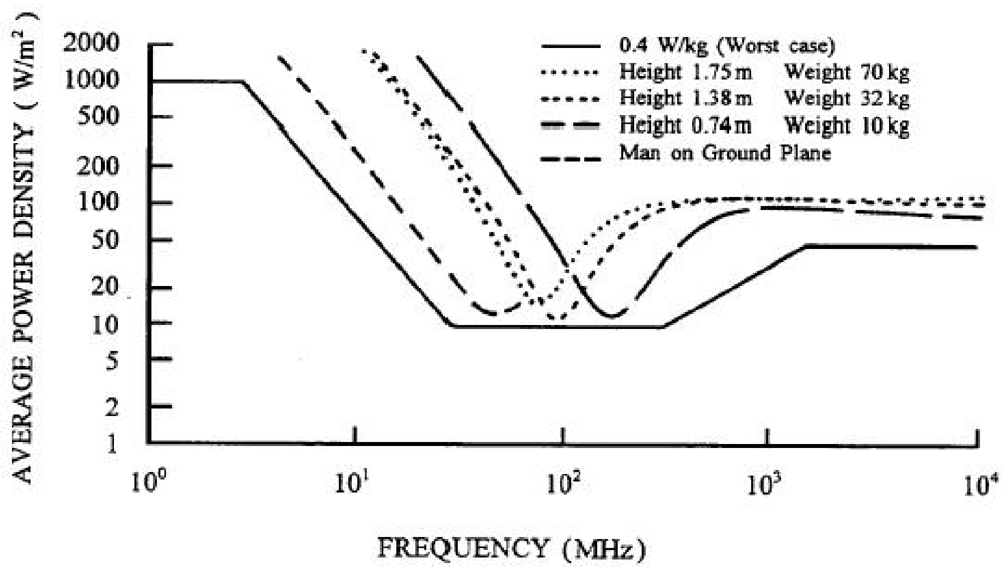

FIGURE A1 POWER DENSITIES THAT LIMIT HUMAN WHOLE-BODY SAR TO 0.4 W/kg
(From Radiofrequency radiation dosimetry handbook(Fourth edition))

Figure 4.4: Measured Power Densities which equates to the whole-body SAR limit of 0.4W/kg (Standards Australia, 1990)

To see what the standard value that is required in W/m^2, Figure 4.4 must be viewed. It can be seen from the graph that the range in which the field strength is required to be lowest is between 20MHz and 300MHz. The corresponding field strength at this level is $10W/m^2$ and this corresponds to what could be the worst case scenario depending on the situation of 0.4W/kg, or the standard restriction. As stated in (Section 2.5.3, page 41), the value of 0.4W/kg corresponds to occupational standard limit.

What is required for this project is the general public standard limit of 0.08W/kg as stated in the standards section. The calculations to change from occupational to general public standards are as follows.

The formula for SAR is SAR = $(\sigma |E|^2) / \rho$
Occupational Value SAR = 0.4W/kg = 10W/m^2 x (σ/ ρ)

$$\mathbf{(\sigma/ \rho) = 0.4/100 = 0.004}$$

General Public Value SAR = 0.08W/kg = E_{Pub}^2 x (σ/ ρ)

$$= E_{Pub}^2 = 0.08 / (\sigma/ \rho)$$

$$= E_{Pub}^2 = 0.08/0.004 = 20$$

$$= E_{Pub} = \text{sqrt}(20) = \mathbf{4.472W/m^2}$$

So the limiting value for general public is 4.472W/m^2. This value is used as it can be directly calculated from our measurements.

The highest values from Table 4.2 are 97.37dBμV/m for a frequency of 910.3MHz, and 95.86dBμV/m for a frequency of 102.7MHz. The frequency value of 910.3MHz is out of the 20MHz to 300MHz range shown in Figure 4.4 and therefore can be discounted as the closest value to the limit.

Using 95.86dBμV/m the calculations are as follows. Refer to (Section 3.3.2, page 67) for more details on the calculations and how they apply.

$$\text{Field Strength } (\mu V/m)\ E = 20\log_{10}(E_{dB}) = 20\log_{10}(95.86) = 39.63\ \mu V/m$$

$$\text{Power Density } (\mu W/m^2) = \frac{E^2}{120\pi} = \frac{39.63^2}{120*\pi} = \mathbf{4.166\ \mu W/m^2}$$

Peak Value = 4.166 μW/m^2 **Limit = 4.47W/m^2**

Our peak value = 1,072,871 times smaller than the standards.

4.2.3 Max Value Conclusion

From the data which has been measured the largest peak value gave a final value that was much lower than the standard. This value was 10^6 times lower than what the standard documents stated, and this level is many times lower than any dangerous level of signal, according to ARPANSA and the standard documentation.

It is concluded that the highest value easily falls within safe boundaries, and so the maximum value shall not be further analysed. What then must be discovered are what comparisons can be seen between different low level signals and how they change dependant upon location.

4.3 Site Comparisons

4.3.1 Comparison Theory

The comparison between sites is a much more complex matter.

There are a number of characteristics which need to be compared. These consist of a) the number of signals present at the site, b) the strength of the signals, c) the variation in the signals over time, d) the time in which the signals are present and e) the effects of orientation changes.

First each site is able to be analysed separately with comparisons to be view later.

4.3.1.1 Laboratory Tests

The results from the Laboratory test were reasonable constant. With a vertical orientation the peaks were of different strengths from 30MHz to 220MHz with the highest peaks present in this area. Lower, but consistent, peaks were found from 570MHz to 800MHz with a few extra peaks around 880MHz and 940MHz to 960MHz.

The peaks from 700MHz and above increased by a large amount when the polarisation was changed from vertical to horizontal, increasing in size to become the prominent peaks for the scans. A typical vertical and a typical horizontal scan are shown below in Figures 4.5 and 4.6.

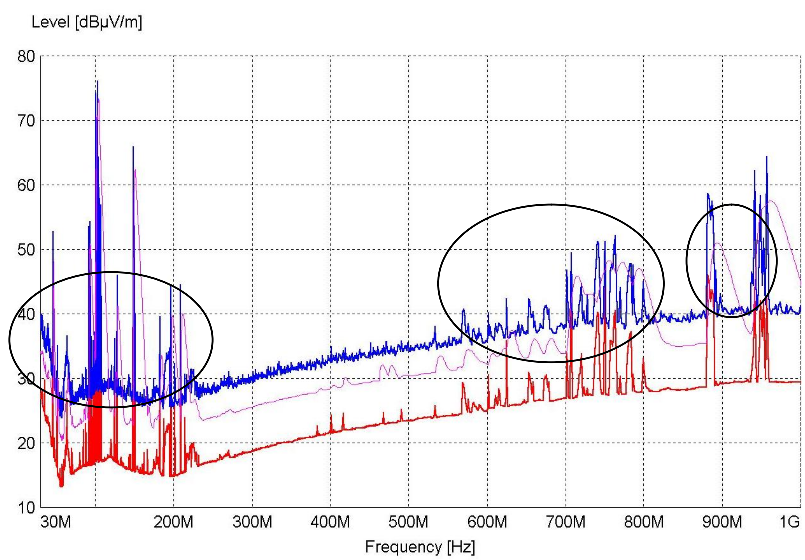

Figure 4.5: Graph showing Scan at the Laboratory site, vertical orientation, between 30MHz and 1GHz.

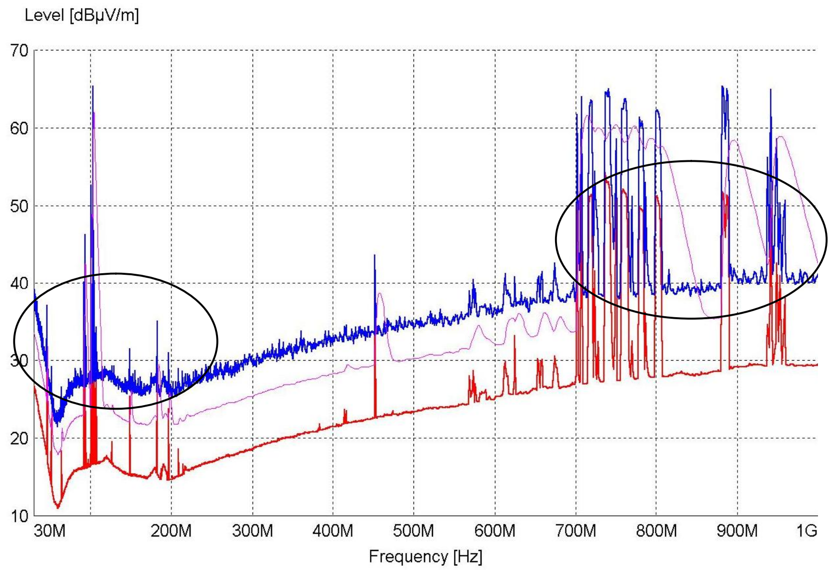

Figure 4.6: Graph showing Scan at the Laboratory site, horizontal orientation, between 30MHz and 1GHz.

4.3.1.2 Lecture Hall Tests

The lecture hall results did vary a little over time. Different peaks appeared, or changed, throughout the different scans. None of these peaks were significantly high and the peaks were very inconsistent and so were not present for much of the time.

The peaks present were rather small, except once again for the 102.7MHz signal. There is little variation between the horizontal and vertical orientation from these scans. The noticeable difference between the orientations was the 102.7MHz peak was on average slightly lower during the vertical polarisation. An example of a typical lecture scan is shown below in Figure 4.7.

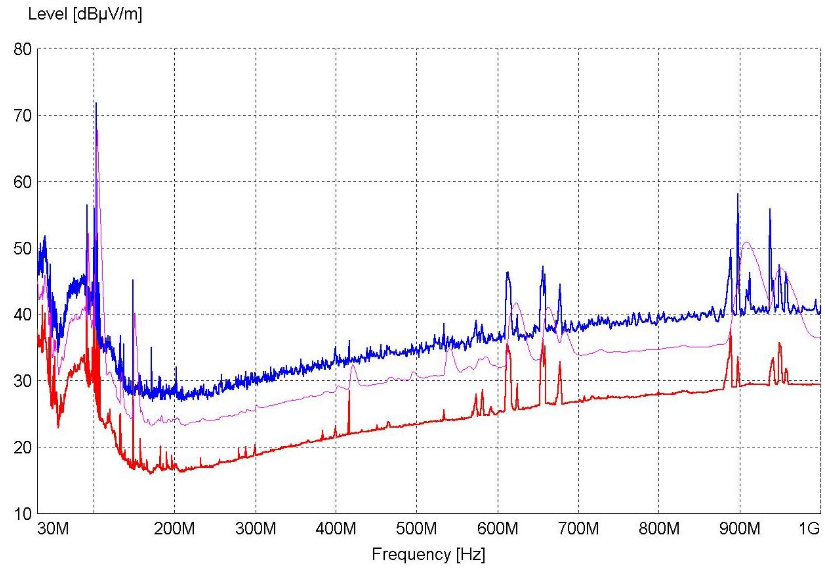

Figure 4.7: Graph showing scan at the Lecture Hall site, vertical orientation, between 30MHz and 1GHz.

4.3.1.3 Z Block Office Tests

The office test was very similar to the lecture hall test, with lower amplitudes but more peaks. The peaks for this site were more constant, with only minor variations in amplitude. These peaks were throughout the whole range and did not change significantly between orientations. Lastly many of the peaks were constantly present, with only a few which appeared at different times.

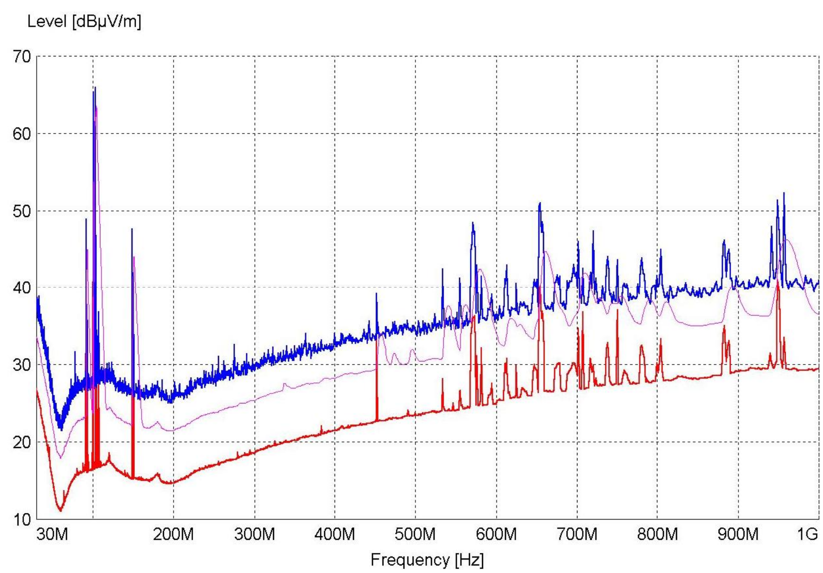

Figure 4.8: Graph showing scan at the Administration Office site, horizontal orientation, between 30MHz and 1GHz.

4.3.1.4 Z-Block Oval Tests

There is very little change over time during the vertical scans at the oval testing location. As well as this there are very few changes in which peaks are present. These peaks are located in a few areas. Firstly the 102.7MHz, and surrounding FM signals, contains a few peaks. Also these are from 550MHz up until 800MHz and finally around 880MHz and 950MHz.

The horizontal polarisation also is very constant but there are a few different amplitudes between each orientation. The 550MHz to 800MHz range for the horizontal orientation has increased amplitude, as well as a few extra peaks. The 880MHz and the 950MHz signals are smaller though for the horizontal orientation. The differences can be seen in the two following Figures, Figure 4.9 and Figure 4.10.

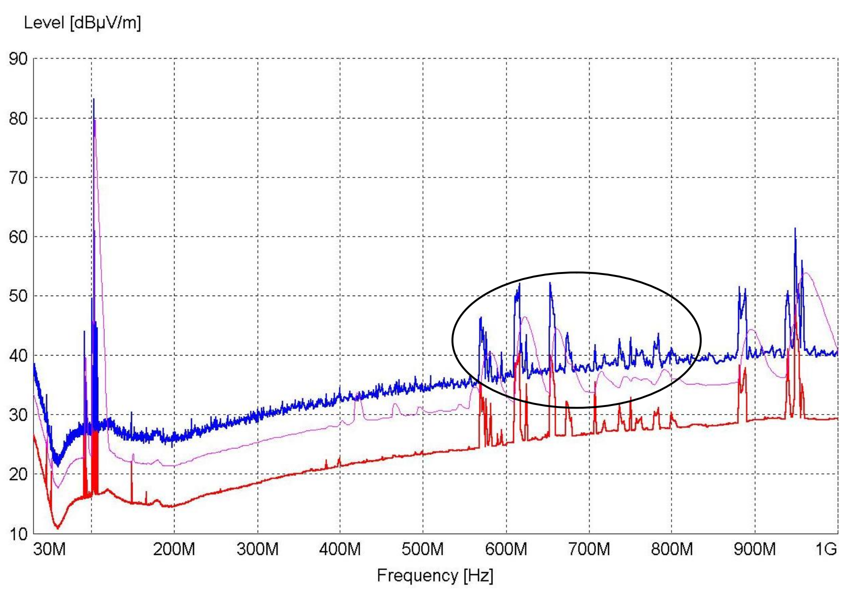

Figure 4.9: Graph showing scan at the Z Block Oval site, vertical orientation, between 30MHz and 1GHz.

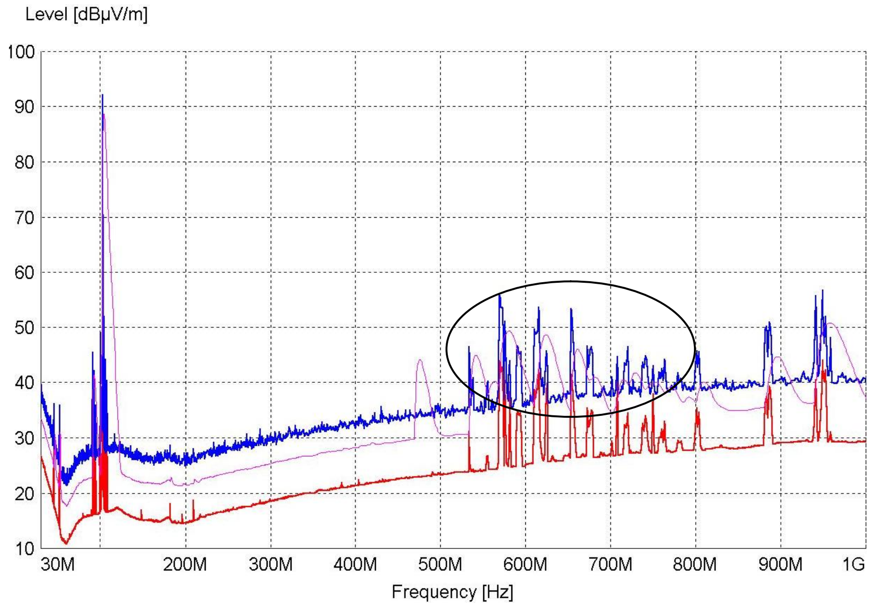

Figure 4.10: Graph showing scan at the Z Block Oval site, horizontal orientation, between 30MHz and 1GHz.

4.3.1.5 Quadrangle Tests

The quadrangle had very few signals that were detected and there was very little variation with the detected signals over time, with no change to which signals were detected. There was also almost no difference between the horizontal and vertical polarisation amplitudes. There are a few signals around the FM radio band, including the highest value for the 102.7MHz signal for all tests. There are also once again a few signals at 880MHz and 950MHz. An example of the typical scan for the quadrangle site is shown below in Figure 4.11.

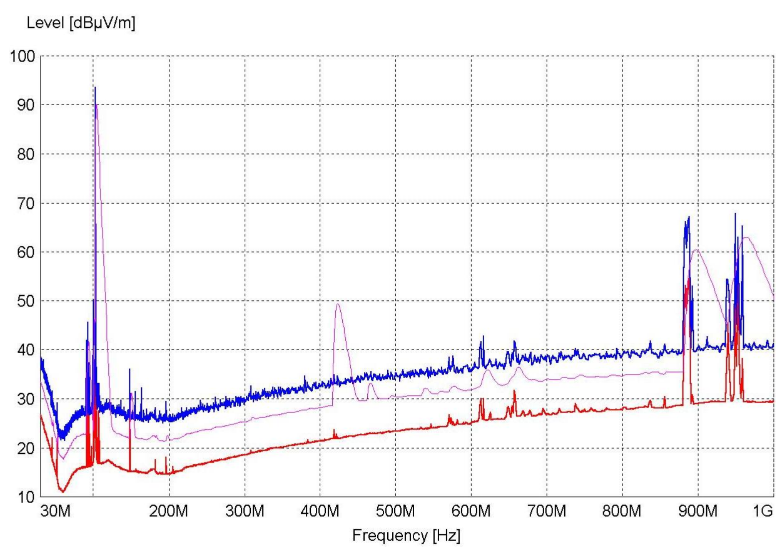

Figure 4.11: Graph showing scan at the Quadrangle site, vertical orientation, between 30MHz and 1GHz.

4.3.1.6 Refect Tests

The scans at the Refect testing location showed an extreme amount of variation. The only constant signal was the high 102.7MHz signal with the rest not being present consistently. There was the capability of very high signals from 880MHz to 1GHz, but the rest of the peaks, when present, appeared to be lower. The scan results were too inconsistent to see a trend for different orientations but overall the number of different peaks was reasonably low.

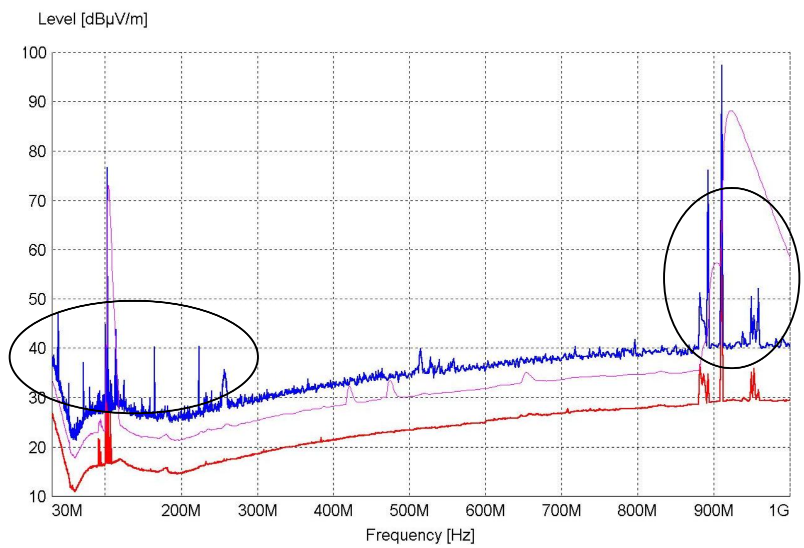

Figure 4.12: Graph showing scan at the Refect site, vertical orientation, between 30MHz and 1GHz.

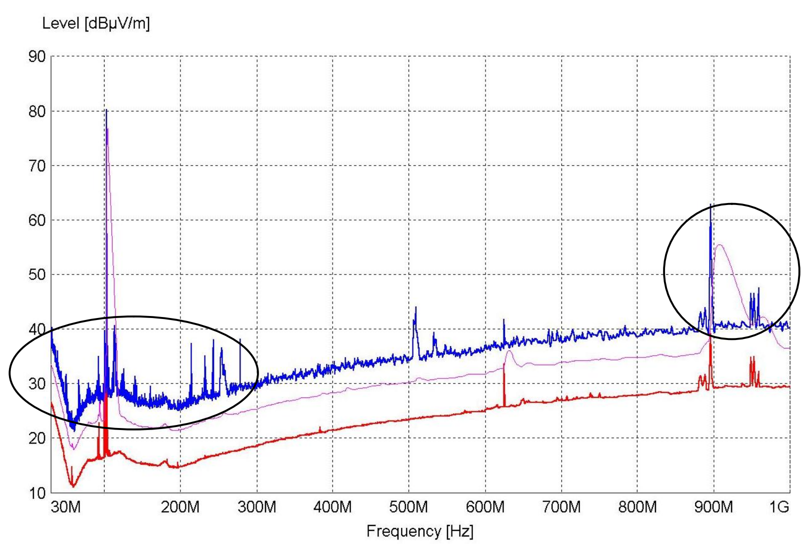

Figure 4.13: Graph showing scan at the Refect site, horizontal orientation, between 30MHz and 1GHz.

4.3.1.7 S Block 5th Floor Tests

The S Block, 5th floor location, provided extremely stable scans. For the horizontal orientation there was a little variation from 30MHz to 220MHz, but very low variation in the peaks located from 600MHz to 1GHz, which contained small to medium amplitude signals. There were a medium number of signals within this range as well. The vertical orientation was also very consistent, but with a lower number, and amplitude of peaks present. There were 4 greatly increased peaks around 880MHz and 950MHz but through the rest of the scan the number of peaks was greatly decreased, and the amplitude also lower.

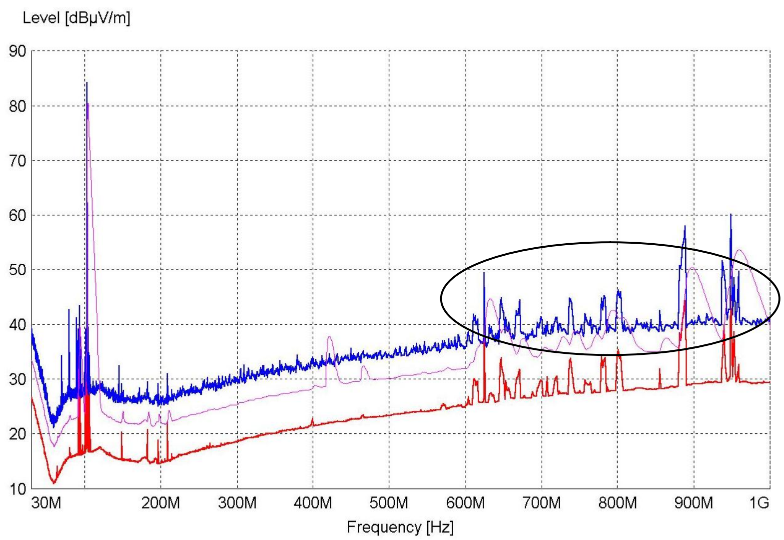

Figure 4.14: Graph showing scan at the S Block site, horizontal orientation, between 30MHz and 1GHz.

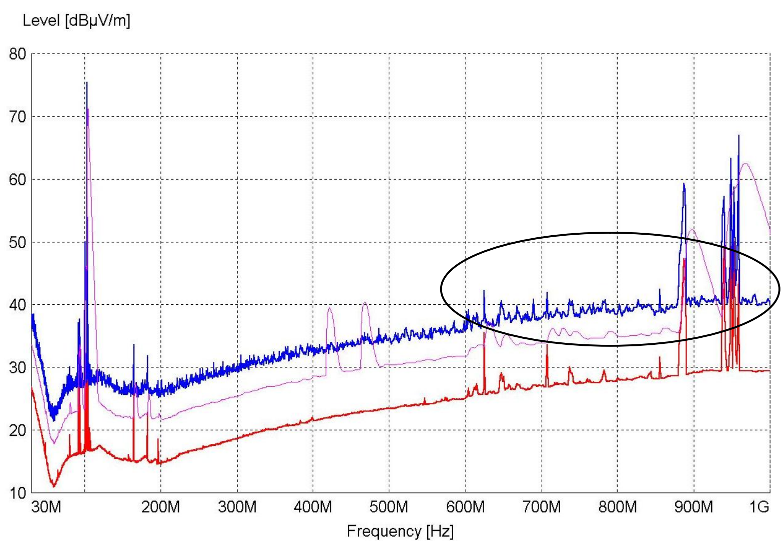

Figure 4.15: Graph showing scan at the S Block site, vertical orientation, between 30MHz and 1GHz.

4.3.1.8 GSM Transmission Tests

The GSM Transmission station was one of the two off-campus locations and so only horizontal orientation scans were taken due to restrictions with the equipment. The scans that were received with the horizontal orientation were extremely stable, with little change, and each signal being constantly present. The signal peaks were also of a medium to high amplitude throughout the whole scan from 30MHz to 1GHz and there were a higher than normal number of signals present. The frequencies of the scans were the FM band around 102.7MHz, 400MHz to 450MHz, 550MHz to 700MHz and finally from 880MHz to 950MHz.

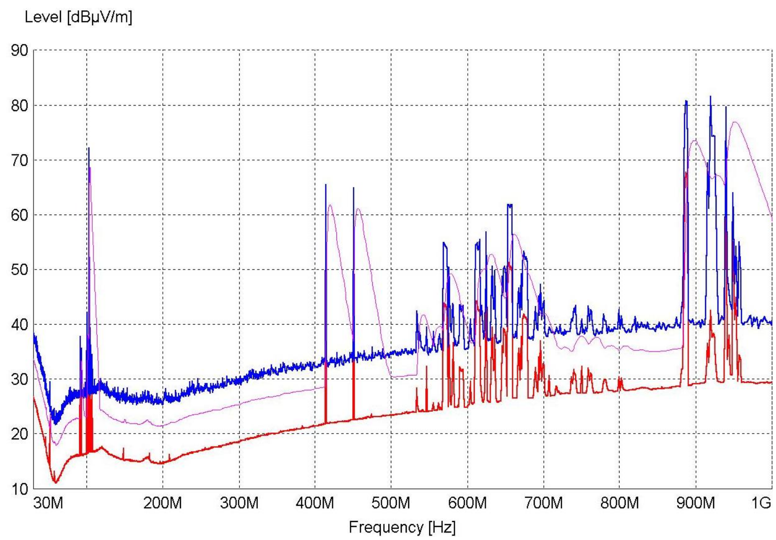

Figure 4.16: Graph showing scan at the GSM Transmission site, horizontal orientation, between 30MHz and 1GHz.

4.3.1.9 Public Park Tests

The park location was one of the two off-campus locations and so only horizontal orientation scans were taken due to restrictions with the equipment. This site contained consistent scans, with little change in signal strength over time, and signals which were constantly present. These signals ranged from a few signals, of a low strength, around the FM radio band of 80MHz to 150MHz, and many higher amplitude signals from 700MHz to 1GHz.

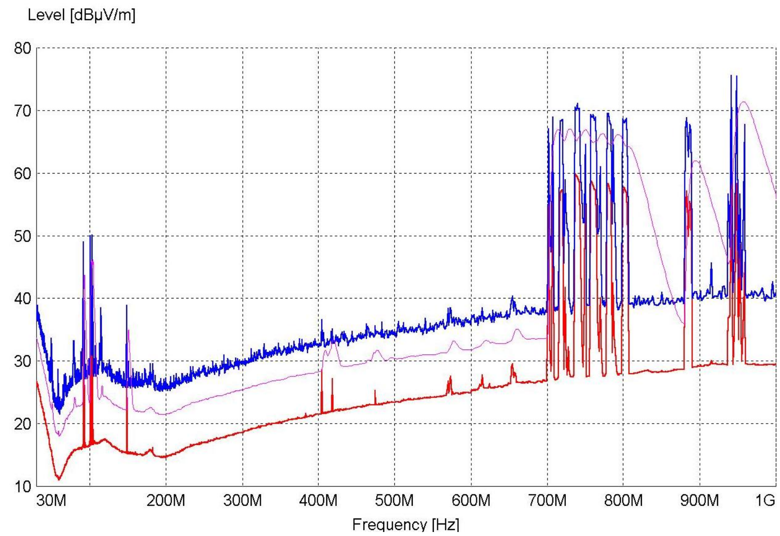

Figure 4.17: Graph showing scan at the Public Park site, horizontal orientation, between 30MHz and 1GHz.

4.3.2 Comparisons between sites

4.3.2.1 Number of Peaks between Locations

One key point of comparison between the sites is if there are more or less signals that are able to be detected. A review of the number of noticeable peaks present for each site is shown from 30MHz to 1GHz can be seen below in Table 4.4.

Table 4.4: Table showing the number of signal peaks detected at each location within the 30MHz to 1GHz frequency range as well as the amplitude of these peaks.

Location	Number of Peaks from 30MHz to 1GHz	Average Amplitude of Peak Signals
Laboratory Test Location	36	54.3
Lecture Hall Test Location	32	49.5
Z Block Admin Office Test Location	36	47.2
Z Block Oval Test Location	29	51.8
Quadrangle Test Location	22	53.0
Refect Test Location	18	56.1
S Block 5th Floor Test Location	23	49.6
GSM Transmission Test Location	23	57.0
Park Test Location	19	60.9

The peak data is taken from the maximums from all the scans, and so only one scan needs to detect a peak for it to be counted. This allows for highly inconsistent sites to still give a total peak Figure as a whole.

So the results from this are as follows. The locations situated in, and around, Z Block contain 36, 36 and 29 peaks, corresponding to the laboratory, administration office and oval test respectively.

The locations found around the centre of the university are the lecture hall, quadrangle, refect and S Block test locations. The number of peaks for these areas are 32 peaks for the lecture hall test, 22 peaks for the quadrangle test, 18 peaks for the refect test and 23 peaks for the 5th Floor S Block test.

The final two off campus locations contained 23 peaks for the GSM transmission site, and 19 peaks for the park test.

The indication of a peak was taken as a significant increase when compared to the baseline of the scan. This was usually taken as around a 5dBμV/m increase or higher, depending on the stability of the baseline. A more in depth analysis of the peaks can be seen below in Table 4.5.

Table 4.5: Table showing the breakdown of peaks present for each site and which frequency range they are in.

Signal f * Range (MHz)	Frequency Range Signal Uses	Z Block Lab	H Block Lecture	Z Block Office	Z Block Oval	Quadrangle	R Block Refect	S Block 5th Floor	Transmission Antenna	Public Park
30	Emergency Services Council						5 Peaks 47.7 Ave 66.5 Max			
80	FM Radio	8 Peaks 60.7 Ave 76.4 Max	9 Peaks 56.8 Ave 77.8 Max	7 Peaks 49.0 Ave 68.1 Max	8 Peaks 51.9 Ave 92.2 Max	7 Peaks 62.1 Ave 95.9 Max		7 Peaks 50.0 Ave 54.9 Max	6 Peaks 44.3 Ave 72.4 Max	
120 130	Council Police Health Paging	8 Peaks 46.0 Ave 66.31 Max	8 Peaks 41.9 Ave 52.3 Max							
200	Police, Fire and Rescue Private Users									
480 530 570	Private Users ie. Taxis			14 Peaks 45.4 Ave 55.8 Max	13 Peaks 51.1 Ave 69.0 Max	5 Peaks 45.6 Ave 48.5 Max			9 Peaks 54.2 Ave 63.9 Max	
620 650	Private	11 Peaks 59.0 Ave 67.1 Max								
700 740 780	TV Broadcasting							8 Peaks 57.3 Ave 68.8 Max		9 Peaks 69.3 Ave 72.4 Max
800 890 950 1000	Mobile Services Main Roads Private Users		5 Peaks 56.7 Ave 62.4 Max			7 Peaks 67.6 Ave 72.6 Max	7 Peaks 68.0 Ave 97.4 Max			

*Signal Frequency Range Scale not linear to allow for lower table size. Values correspond to specific data.

To use this table how it works must be explained. The frequency values on the left denote the start and end of the frequency range, and these ranges are broken up into the main applications, such as FM radio, private use or mobile phone signals.

Then each column refers to a single site location, and the information in the column shows the range in which groups of peaks were found. Each of these areas contained three points of information, the number of peaks, the average value of these peaks, and the highest peak value within that range.

The data obtained from this table can show some very significant information.

Nearly all locations contained a group of peaks based around the FM radio band. The only two which did not were the Refect Test and the Public Park Test. As well as this all contained around 7-9 signals detected within this range.

4 locations contained significant peaks based around the mobile phone range of 880MHz to 950MHz. These were the H Block Lecture hall test, the Refect test, the quadrangle test and the S-Block 5th Floor Test. These are the 4 locations found around the centre of the university and while this could be coincidence this is also the main locations which do contain a high amount of mobile phone users.

The frequency range between 120MHz and 850MHz contained a number of peaks for different locations, but there were no consistent patterns within this range, and groups of peaks were different for each location.

4.3.2.2 Amplitude Fluctuation within Sites

As previously stated what needs to be seen are any peaks that can be seen in each scan, at each location. These signals have the potential to change over time and this variation over time may be different depending on the signal or the site.

A study into these variations is required to see if there are any patterns. To observe the variation a few signals were chosen, which were signals present in the majority locations (either found in 7, 8 or 9 locations out of all 9 locations).

By narrowing the scans down to just the 7 signals that are present on more occasions it is possible to remove a lot of unnecessary information and simplify things down to manageable levels. This still means that a graph for each site is required, but this contains much less information as otherwise needed. These graphs are shown here below, and a discussion on the outcomes of these graphs discussed afterwards.

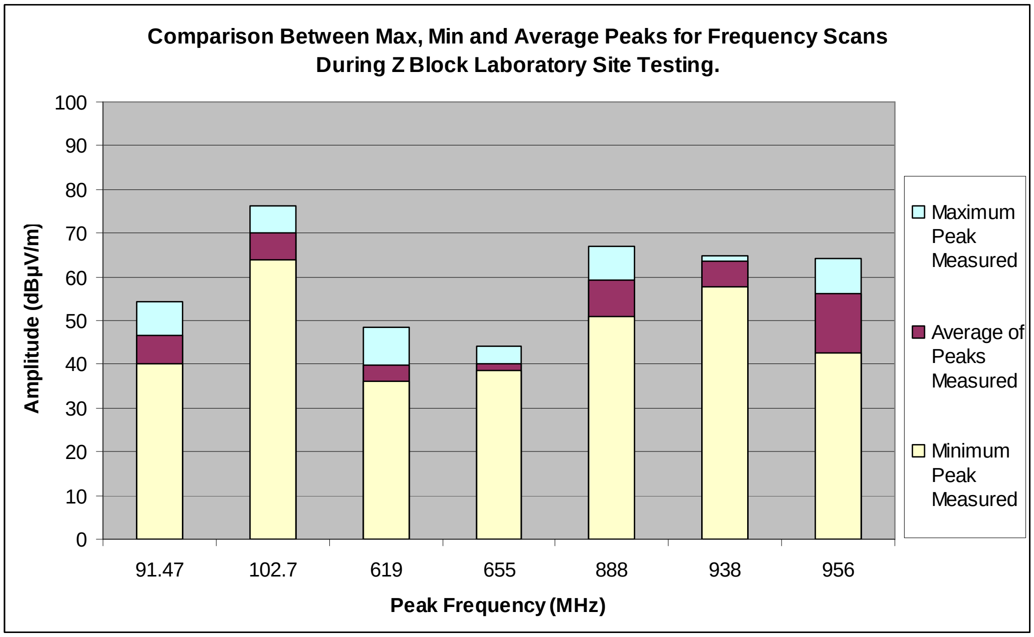

Figure 4.18: Graph showing the max, min and average amplitude values of chosen frequencies within the Z Block Laboratory Site scans.

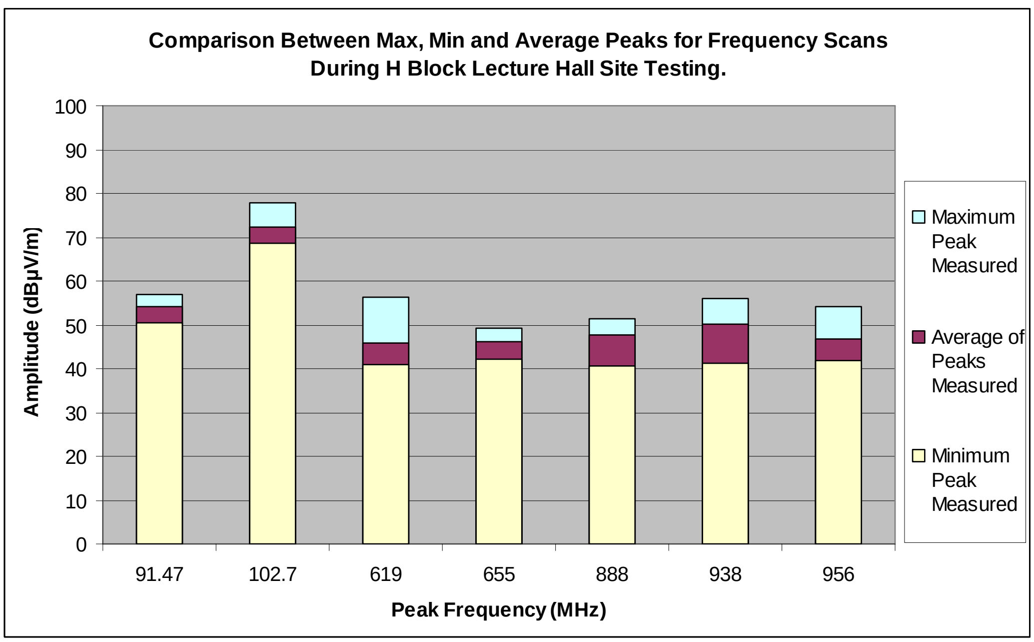

Figure 4.19: Graph showing the max, min and average amplitude values of chosen frequencies within the H Block Lecture Hall Site scans.

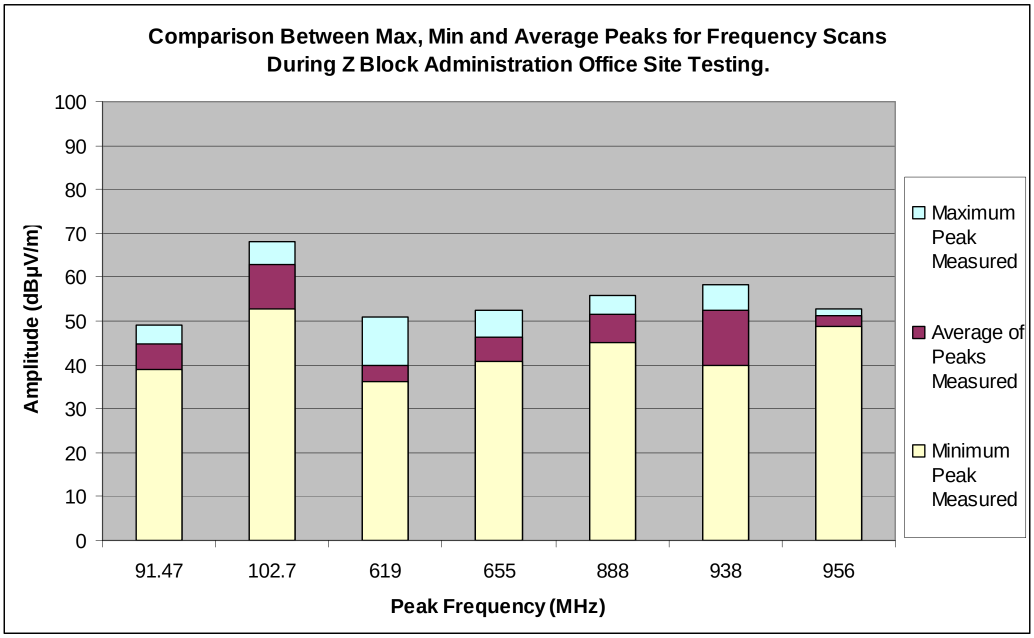

Figure 4.20: Graph showing the max, min and average amplitude values of chosen frequencies within the Z Block Administration Office Site scans.

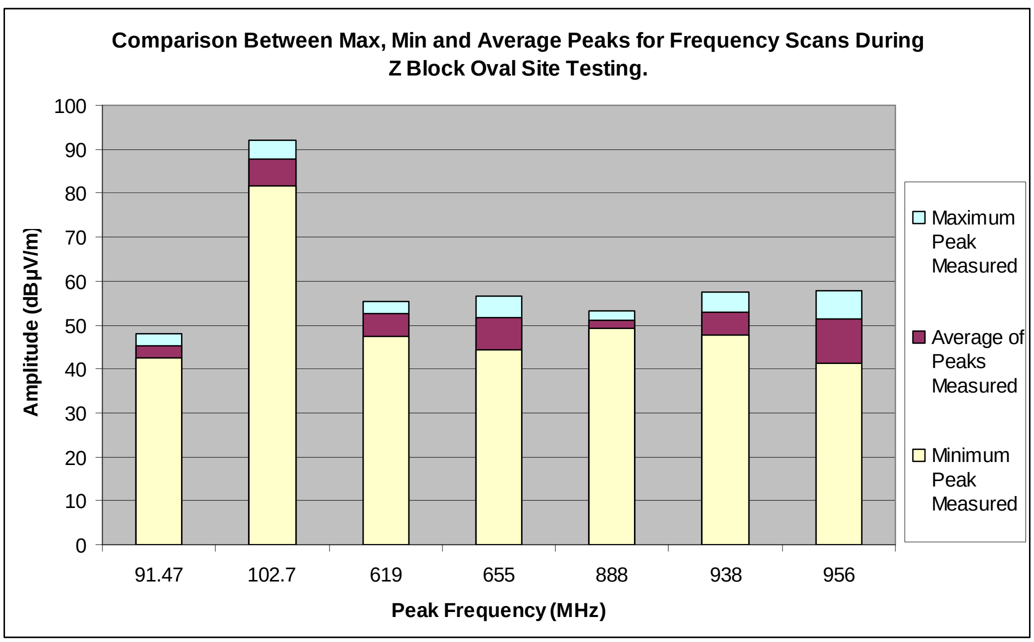

Figure 4.21: Graph showing the max, min and average amplitude values of chosen frequencies within the Z Block Oval Site scans.

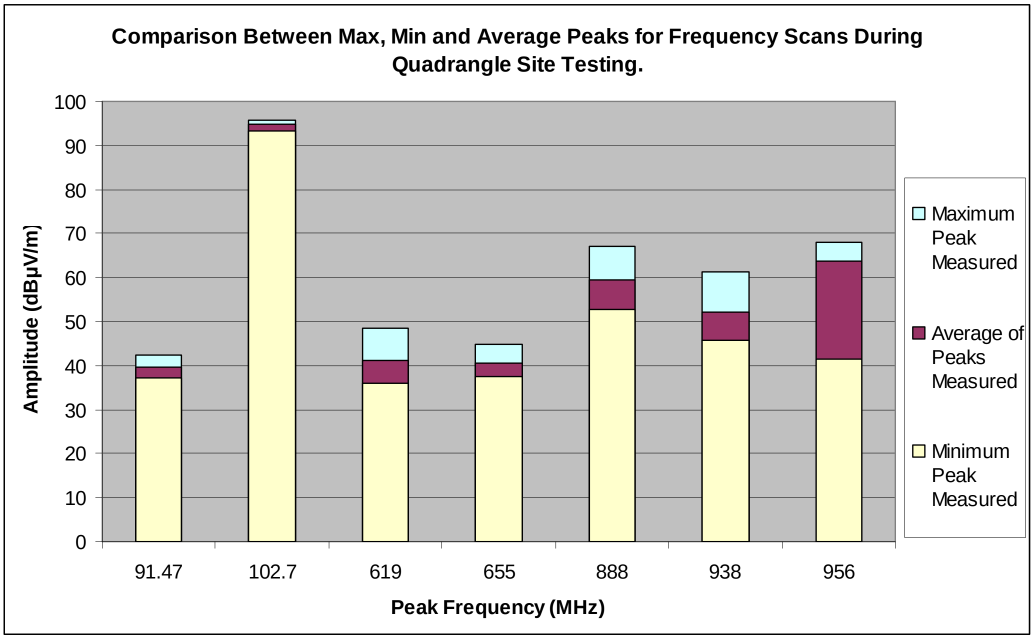

Figure 4.22: Graph showing the max, min and average amplitude values of chosen frequencies within the Quadrangle Site scans.

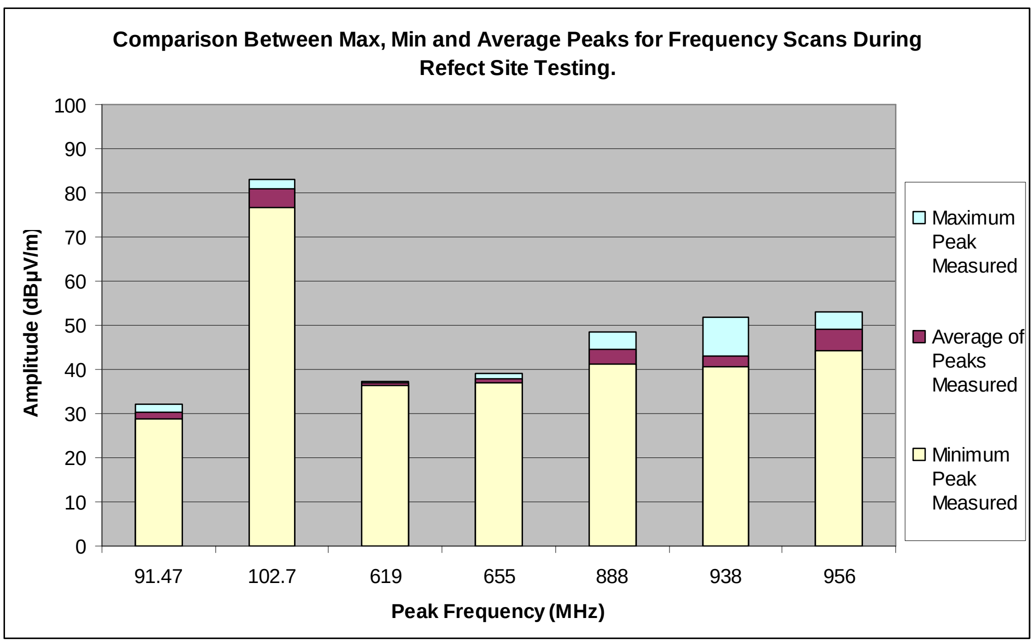

Figure 4.23: Graph showing the max, min and average amplitude values of chosen frequencies within the Refect Site scans.

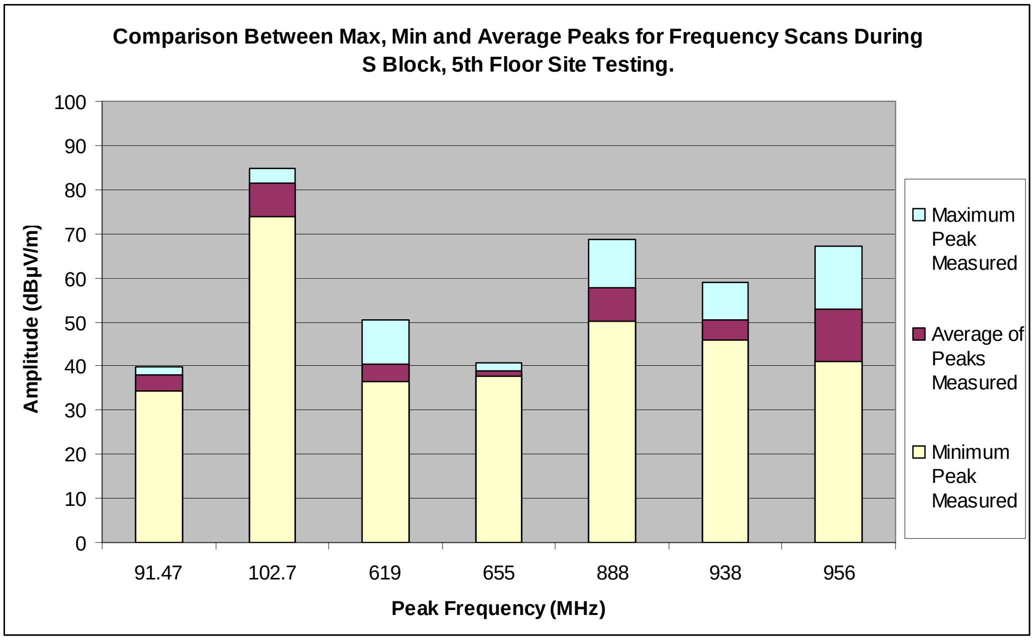

Figure 4.24: Graph showing the max, min and average amplitude values of chosen frequencies within the S Block, 5th Floor Site scans.

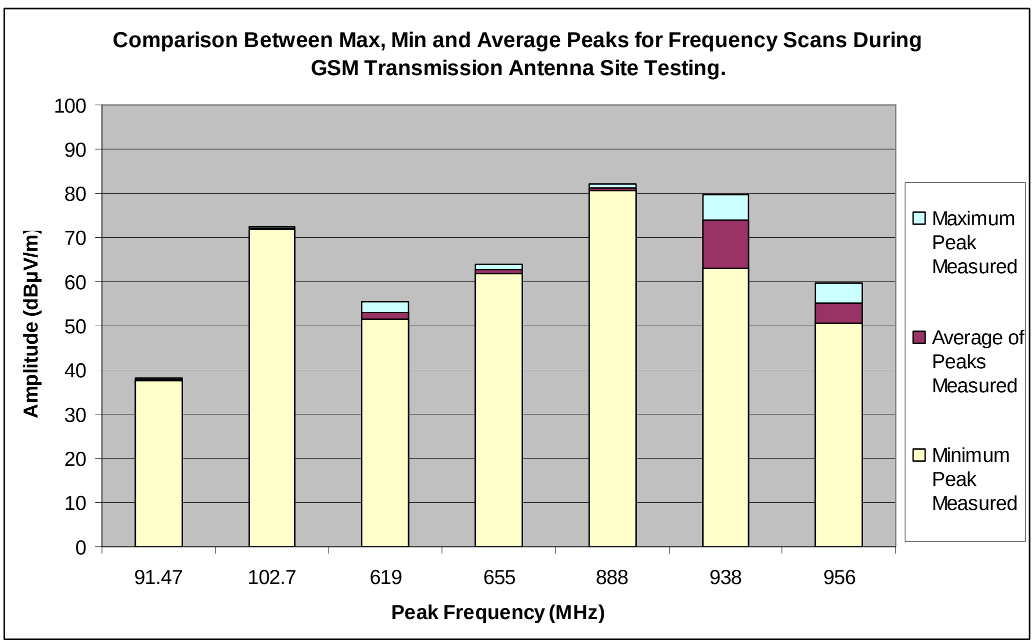

Figure 4.25: Graph showing the max, min and average amplitude values of chosen frequencies within the GSM Transmission Antenna Site scans.

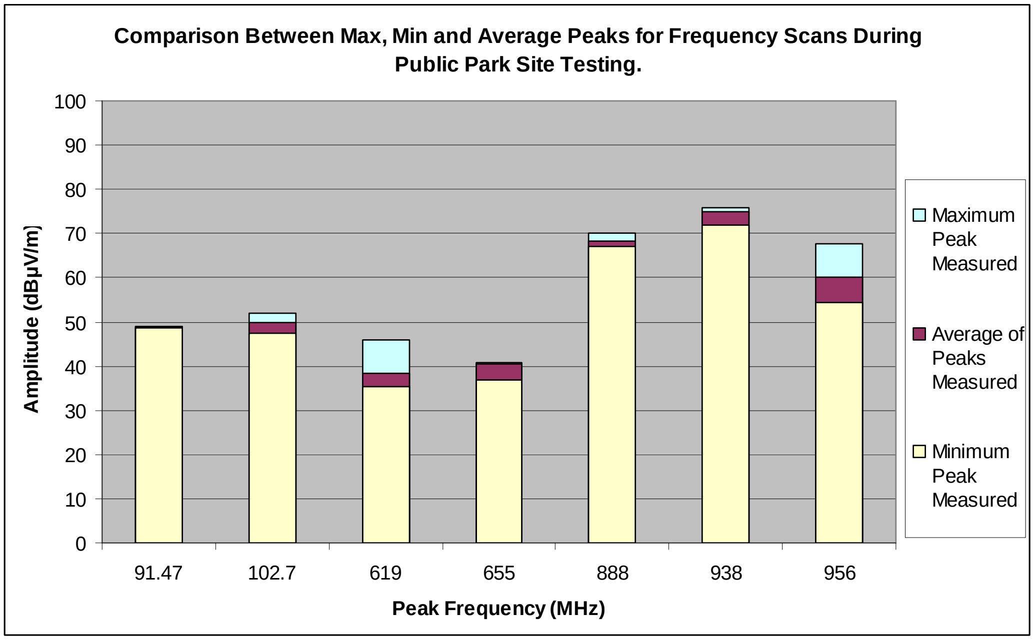

Figure 4.26: Graph showing the max, min and average amplitude values of chosen frequencies within the Public Park Site scans.

There are two ways to analyse these graphs. Firstly a comparison between the signals between each site can be finished and secondly a trend for each site can be investigated.

The highest amplitude variation for a single frequency at a single site occurred at the S Block, 5th floor location. The 956MHz frequency signal varied from 41dBμV/m to 68dBμV/m. This is a difference of 27dBμV/m which is a round a 40% variation in the signal amplitude.

4.3.2.3 Comparison of Single Signals Over all Sites

Looking at a single signal and viewing how the variation changes for each site gives few patterns or trends which can be viewed. For example the 888MHz frequency signal has 4 sites which had almost no variations, 3 sites in which it had a medium level of variation and 2 sites which had a high level of variation in the signal. These changes in variation could not be seen to form any trend and gives very little useful information.

The other frequencies also had almost not patterns but one which could be deduced was the high frequency signals of 938MHz and 956MHz did show a greater variation then the other signals in almost all instances. This shows that the signals around these frequencies appear to have a much higher variation and are less consistent as most other frequencies.

4.3.2.4 Comparison of Sites, Viewing all Signals.

Looking at each site as a whole it is possible to see which sites have larger variation and which have smaller. The two off-campus sites seemed to have a lower signal variation than any on-campus sites. Also it can be noted that the refect testing also had a low signal variation for its measurements. This is the only surprising result, as it was predicted that all the on-campus sites would contain a similar level of variation between the sites, as they are all exposed to mainly the same signals. But the Refect did not show this, and was located in the middle of all the on-campus sites.

The site which showed the highest variation with all of its results was the S-Block 5th floor Site. The scans from this site had some of the highest variations, with only one frequency showing a low level of variation.

The difficulties which occurred with seeing patterns at each site are dependant on the high variability of some signals and the number of scan taken for each site. The average, max and minimum were taken from a total of 12 scans and this is not a high enough sample size to conclude that any trend represents the long term characteristics of a signal. For example the TV broadcast signals may be detected at a time when a television program is being broadcast, but the signal may significantly change for a different program, or when adverts are present, and with only 12 scans it cannot be certain that the results depict overall trends of each signal.

4.3.2.5 Average Amplitude Variations between Sites

The previous section looked at the change in signal variation between each site, this section deals with only the change in the overall signal strength for amplitudes measured at each site. This is compared through the overall average of signals measured for each site. Once again the same 7 frequency signals will be compared as these are the most common signals present through the experimentation.

The following graph, while quite complex, contains all the information needed. Each site has been shown as a group of averages for the 7 chosen measured signals. The 7 signals are colour coded according to the legend and so each site can be viewed individually, or each signal viewed individually across the site using the colour. The average amplitude was just the average of all scan values taken.

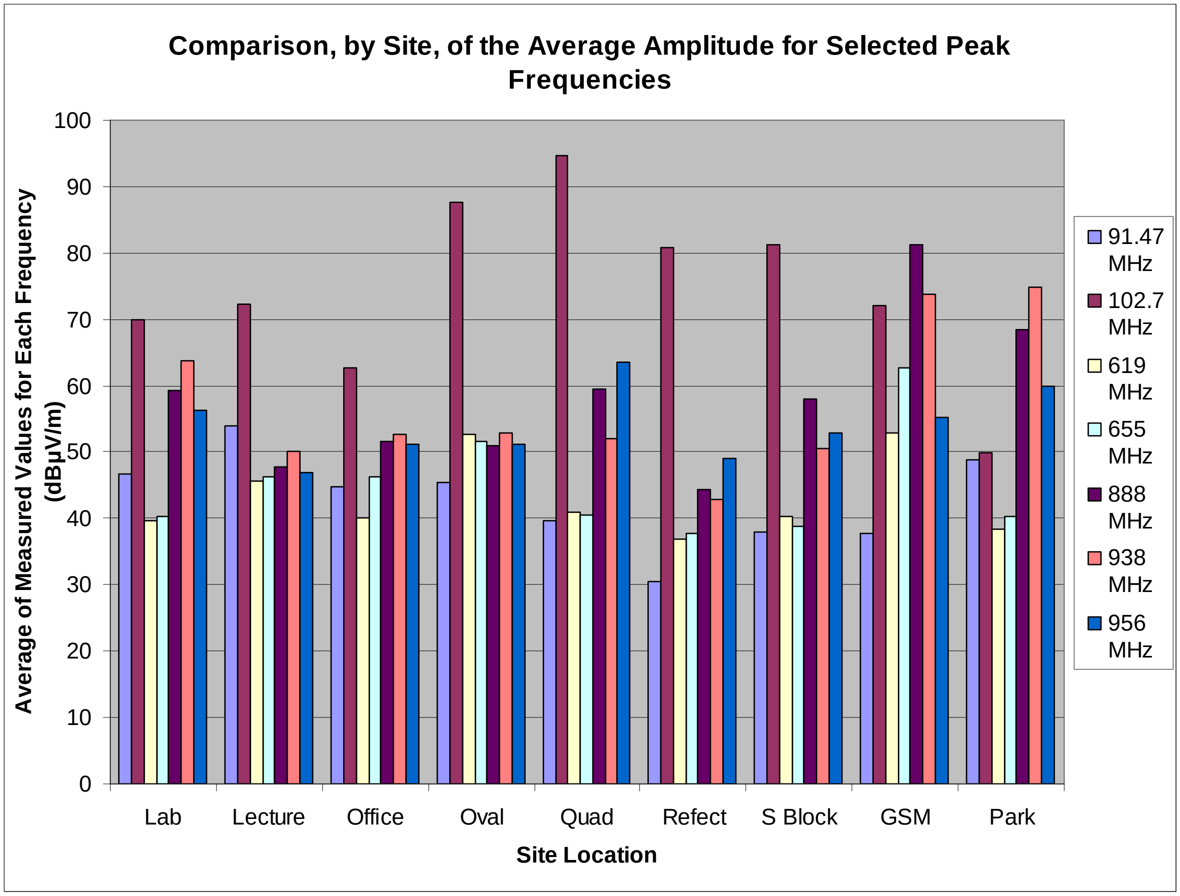

Figure 4.27: Graph showing the resulting average amplitude of signals taken, shown by location and frequency.

4.3.3 Patterns and Trends between Sites

From the graph above two conclusions can be made of the sites with the largest and smallest exposure. The site with the highest signal amplitude exposure was the GSM transmission site. This site had 3 signals above 70dBµV/m, 1 more above 60dBµV/m and 2 more above 50dBµV/m. These are significantly higher, in total, than all the other sites and so is regarded as the highest exposed site overall for these chosen frequencies.

The lowest exposed site was concluded to be the Refect location. This site only had one signal above 50dBµV/m, which was the 102.7MHz signal which all sites recorded large numbers for. Many of these measured values would not be regarded as peaks by the standard of peak identification used, and so for these 7 chosen frequencies this site had the lowest overall exposure.

4.3.3.1 102.7 MHz S Block Transmission Antenna

The first pattern to emerge is in regard to the 102.7MHz signal which is broadcast from the roof of S-Block. The two highest values for the 102.7MHz signal were measured from the Quadrangle and the Oval site, both of which are outdoor locations. After this the next two were the Refect and at 5th floor, S-Block. The lecture hall, the Z block Lab, and the GSM transmission site contained the next highest peaks with the Z-Block Office a little lower and the public park providing the lowest.

The public park was expected as it was the furthest site from the university and the antenna was faced away from the university. The significant trend is that the outdoor locations seemed to detect a higher signal than the indoor locations.

The Z Block Oval, while being further away than the Refect and especially the S Block Site, had a higher measured peak than both, and the GSM transmission location contained the same strength peaks as the lecture hall and the laboratory sites, despite being more than a kilometre away.

It also was surprising to note that the S-block test location, which was about 5m from the S Block antenna, had the third lowest signal strength on average. This provides some evidence that it is not the distance from a source which can have the main effect on the amplitude but the environment conditions. Two reasons this may have occurred is firstly that the building provided shielding from the antenna signal and secondly that the antenna is designed to transmit horizontally, rather than vertically, so those under the antenna are exposed to a naturally dampened signal. In this case the workers that are constantly exposed to a signal that is less than 20m away from the antenna are lower than those around 200m away, but are outside.

4.3.3.2 Overall Amplitude Trends

While it is hard to make definitive comparisons between these sites it appears that the four outdoor locations, the Z block oval, the Quadrangle, the GSM transmission Antenna and the Public Park appeared to have a slightly higher exposure in general than the indoor sites. This may be coincidence but it appears that the structural protection of the buildings has at least a slight ability to dampen the signal amplitude.

4.3.3.3 91.4MHz, 619MHz and 655MHz signal comparisons

These three signals may seem unrelated but appear to have distinct areas of signal strength. Around the university these three signals were within 5dBμV/m of each other, with the two 600MHz signals having similar amplitude values and the 91.4MHz signal being slightly higher or lower. This can be seen in all university locations, with slight variation at one or two sites. However at the GSM transmission antenna site, about 1-2km to the south west of the university the value of the 619MHz signal was significantly higher than the 91.4MHz signal and the 655MHz signal significantly higher again.

Also the results from the public park area, a few kilometres to the north east of the university measurements gave the opposite results. Both the 619MHz signal and the 655MHz signal were both significantly lower than the 91.4MHz signal, this amplitude being more than 10dBμV/m lower.

The conclusion from this data is that the 91.4MHz signal originates from the North to North East, maybe being located around downtown Toowoomba or the northern suburbs. The two 600MHz signals then could be believed to have their source to the south west of the university as this would explain this pattern seen in the experiment. USQ campus then appears to be at around amplitude mid point. This is the area where all three signals have roughly the same amplitude despite being from three different sources.

Verification of the conclusions has found that the 91.4MHz signal (which is the 91.5MHz radio station Country FM) is located in North Toowoomba towards Highfields. The location of the 600MHz signal was unable to be discovered.

4.3.3.4 Final Notes

The averages recorded for each site shown are difficult to analyse. From looking at the results the trends and patterns are difficult to discern and may be coincidental. With the signals having the ability to vary quickly at unknown times and levels it is difficult to recognise true trends and the results which are present show more of a random pattern than anything else for many of the signals. A discussion can be found later, in Chapter 5 (page 110).

4.3.4 Polarisation Differences

The last point of interest is the differences experienced due to signal orientation. The antenna was used to measure both the horizontal orientation and then the vertical orientation at almost all sites. This was restricted by the antenna stand at the off campus sites, and was restricted by time during the Z Block Administration Office testing. At the off campus sites there is only horizontal orientation scans, and for the office site there is only two full horizontal orientation scans rather than four with the four extra scans of FM and Mobile signal ranges.

The following graphs show comparisons between the horizontal average amplitude and the vertical average amplitude for the 7 signal frequencies chosen.

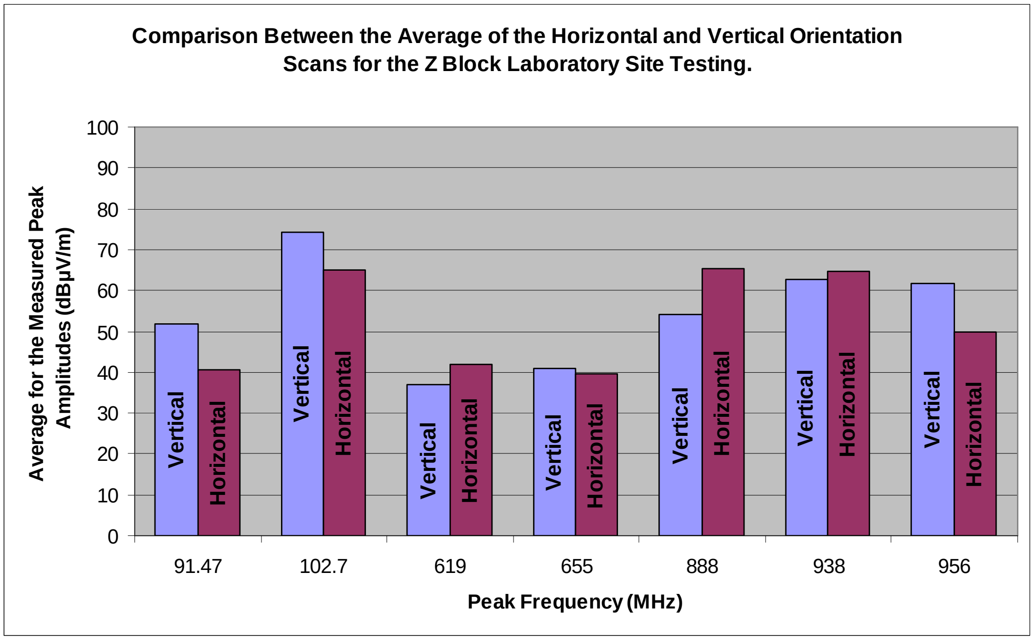

Figure 4.28: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the Z Block Laboratory Test Location.

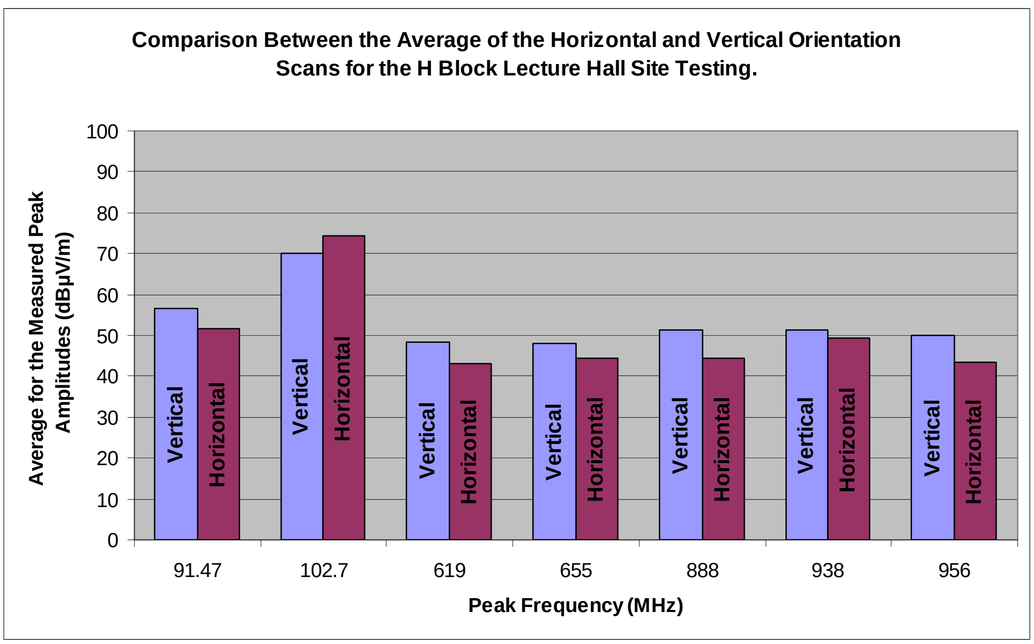

Figure 4.29: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the H Block Lecture Hall Test Location.

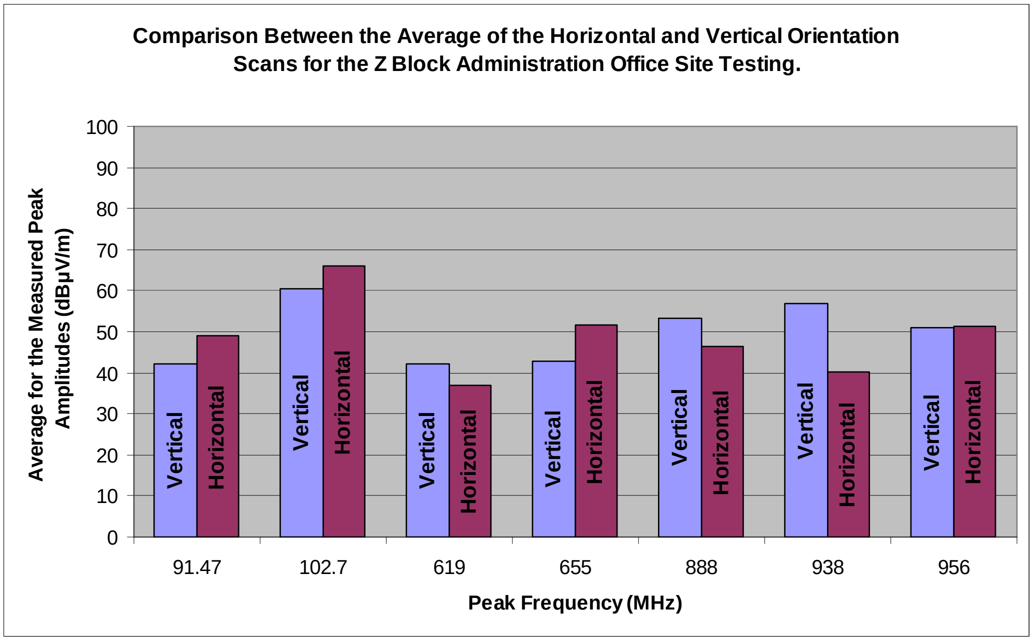

Figure 30: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the Z Block Administration Office Test Location.

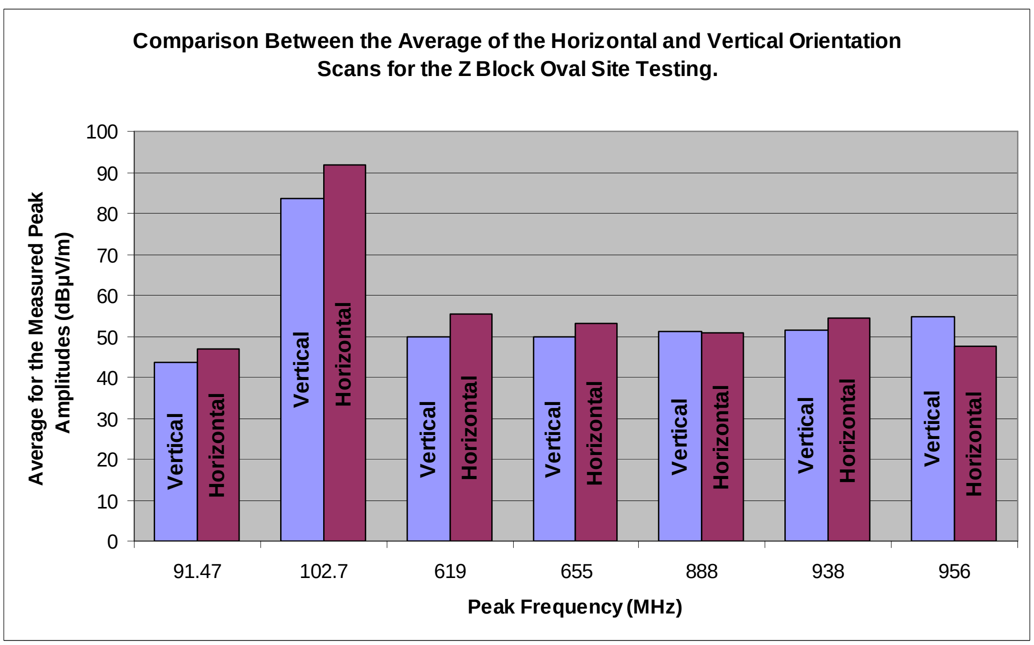

Figure 4.31: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the Z Block Oval Test Location.

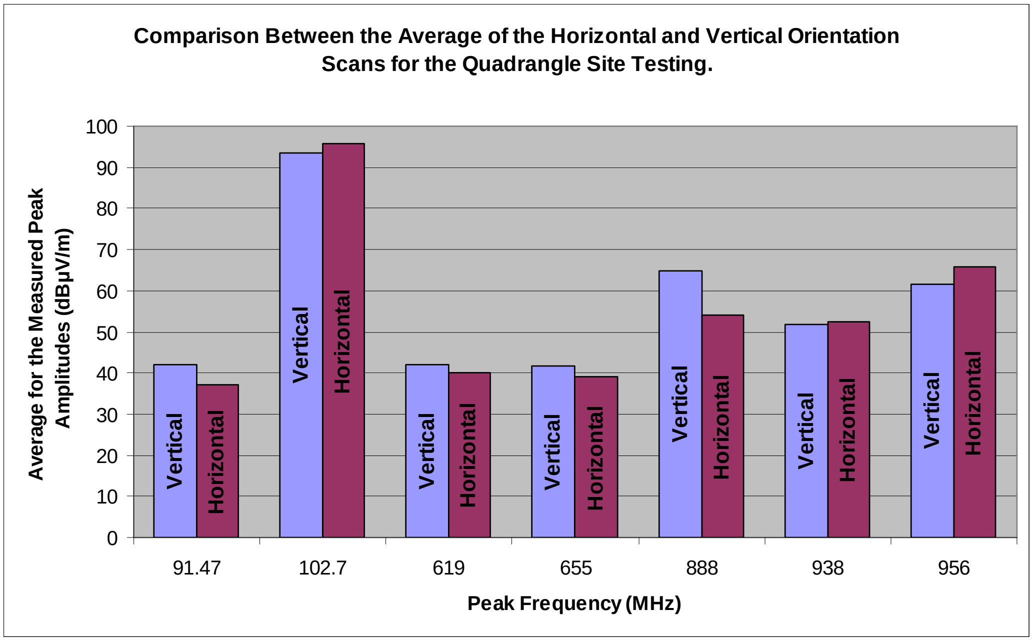

Figure 32: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the Quadrangle Test Location.

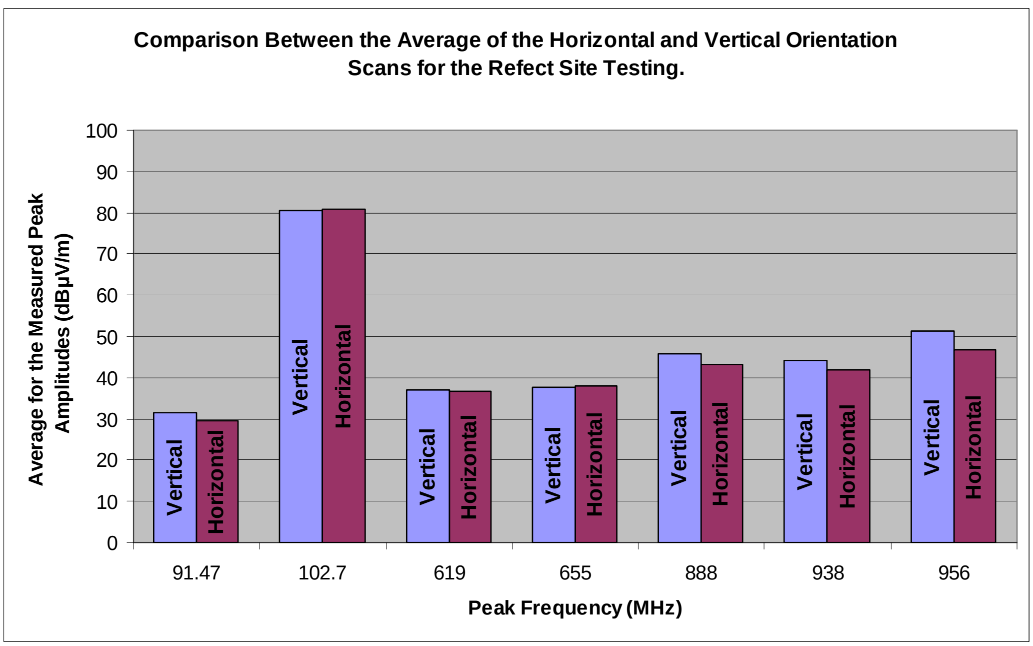

Figure 4.33: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the Refect Test Location.

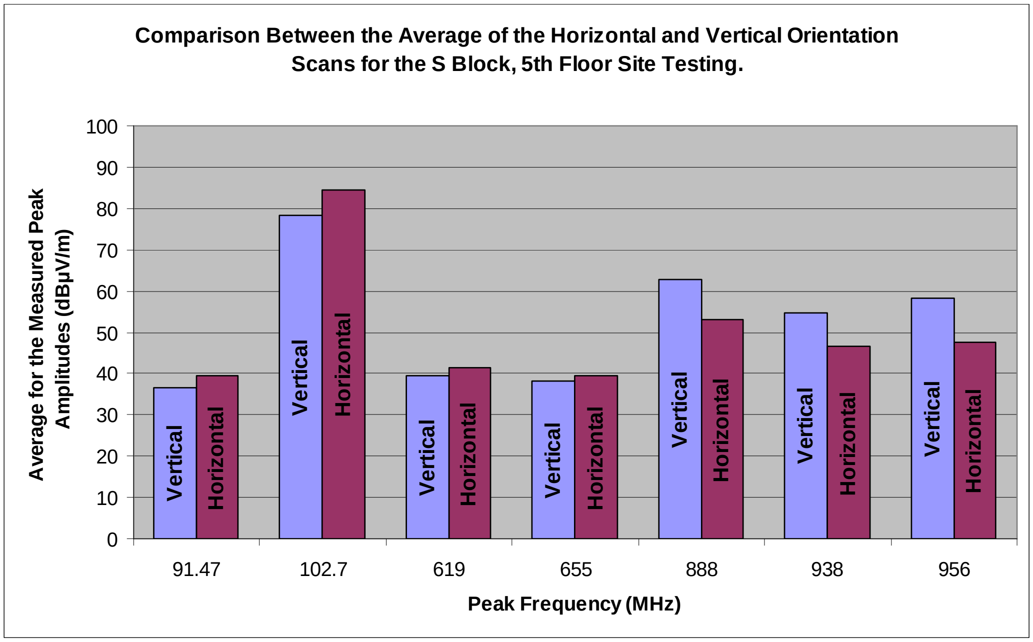

Figure 4.34: Graph showing Horizontal and Vertical Average Amplitudes for Selected Frequencies taken at the S Block, 5th Floor Test Location.

From the graphs provided above it can be seen that the horizontal and vertical amplitudes of the seven signals inspected are constantly changing in comparison to each other. Viewing the 619MHz signal three of the seven locations it has higher horizontal orientated amplitudes than its vertical orientated amplitude. A further three times it has higher vertical polarised amplitudes than horizontal polarised amplitudes and once it is even. In this regard the value is constantly changing but no polarisation tendency can be concluded for this signal from the data retrieved.

In general all the other signals are the same. Some may have a tendency to either horizontal or vertical but it cannot be concluded that the original source is orientated either way due to the constantly changing results not giving a clear horizontal or vertical orientation trend.

The signals that were looked at above have shown that most signals do not have a noticeable orientation bias but there are a few situations in which orientation bias occurs. These are shown below in the following Figures.

The most noticeable orientation bias was found during the Z Block Laboratory Testing. This can be seen in Figure 4.35. The average value of the vertical polarised signals is around 49dBµV/m while the average signal value for the horizontal polarisation is approximately 63dBµV/m. These amplitudes were quite consistent and so that it can be concluded that the signals found from 700MHz to 800MHz are horizontally polarised.

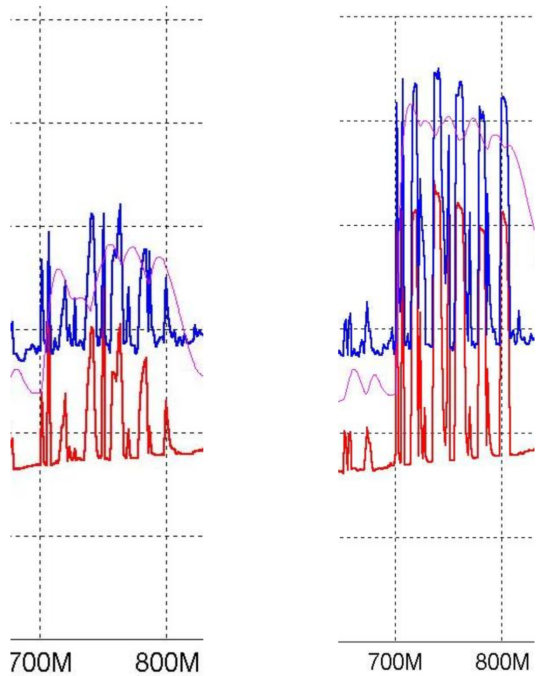

Figure 4.35: Comparison of the 700MHz to 800MHz signals as tested at the Z Block Laboratory Test Site. The left has the antenna based at a vertical orientation; the second is when the antenna is based at a horizontal orientation.

Shown below are two more sites in which orientation bias occurred. The first is the Z Block Oval as shown in Figure 4.36 In this case the amplitude of the peaks wasn't significantly higher, but more peaks were detected when the antenna was orientated horizontally.

The second location was the S Block 5th Floor site and during vertical antenna orientation there was almost no signal peaks present. When change to horizontal orientation a number of peaks appeared which could not be previously detected. This can be seen in Figure 4.37.

There was no evidence of a stronger vertical polarisation at any sites or scans, but with this evidence of horizontal polarisation between 500MHz and 800MHz (with a higher significance from 700MHz to 800MHz) signals can be seen that could be determined to have a horizontal polarisation when being detected on campus.

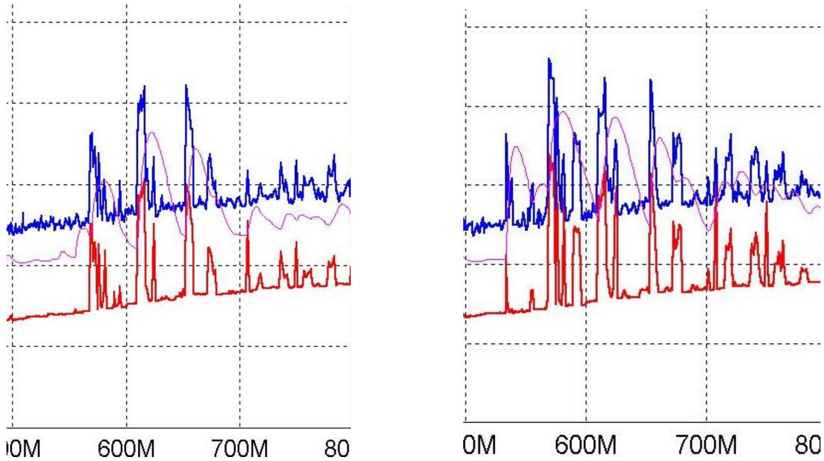

Figure 4.36: Comparison of the 500MHz to 800MHz signals as tested at the Z Block Oval Test Site. The left has the antenna based at a vertical orientation; the second is when the antenna is based at a horizontal orientation.

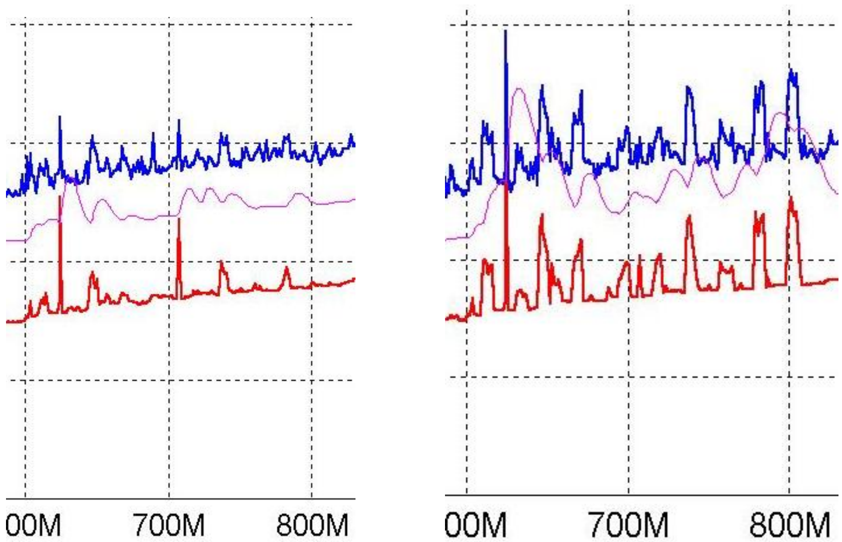

Figure 4.37: Comparison of the 600MHz to 800MHz signals as tested at the S Block 5th Floor Test Site. The left has the antenna based at a vertical orientation; the second is when the antenna is based at a horizontal orientation.

4.3.5 Dipole Signal Analysis

The dipole antenna was used to find the frequency of peaks from 1GHz to 2GHz. The effectiveness of the amplitude readings from this antenna can be in doubt due to its rough construction and no calibration, but if there are signals detected by the antenna it is safe assume that there is a signal present even if the amplitude is not accurate. If a signal is not detected it also does not mean that no signal is present as if the dipole antenna has gaps in its signal detection, or a great dampening effect at certain frequencies it is possible that no signal is detected when one is present.

In general the scans from the dipole showed very little activity from 1GHz to 2GHz for most sites. The sites which had no signals at all detected were the

Z Block Administration Office and the H Block Lecture Hall (except two signals detected for the lecture hall). The two sites which contained a large amount of signals peaks from 1GHz to 2GHz were the Refect and the GSM Transmission Tower Location.

Two of the Refect scans are shown below in Figures 4.38 and 4.39. Both scans show large amount of peaks until 1.4GHz. There still were quite large amounts of peaks 1.4GHz to 2GHz but this was a decrease when compared to 1GHz to 1.4GHz. This shows that there are a fair few signals present at the Refect within this frequency range and so with the right equipment scans of this range should provide sufficient data to analyse this range.

The scan shown of the GSM Transmission Antenna in Figure 4.40 also contains a number of peaks from 1GHz to 1.75GHz. While there is little analysis of these results, these scans provide evidence that further investigation into this frequency range would be beneficial and provide many results for at least two locations.

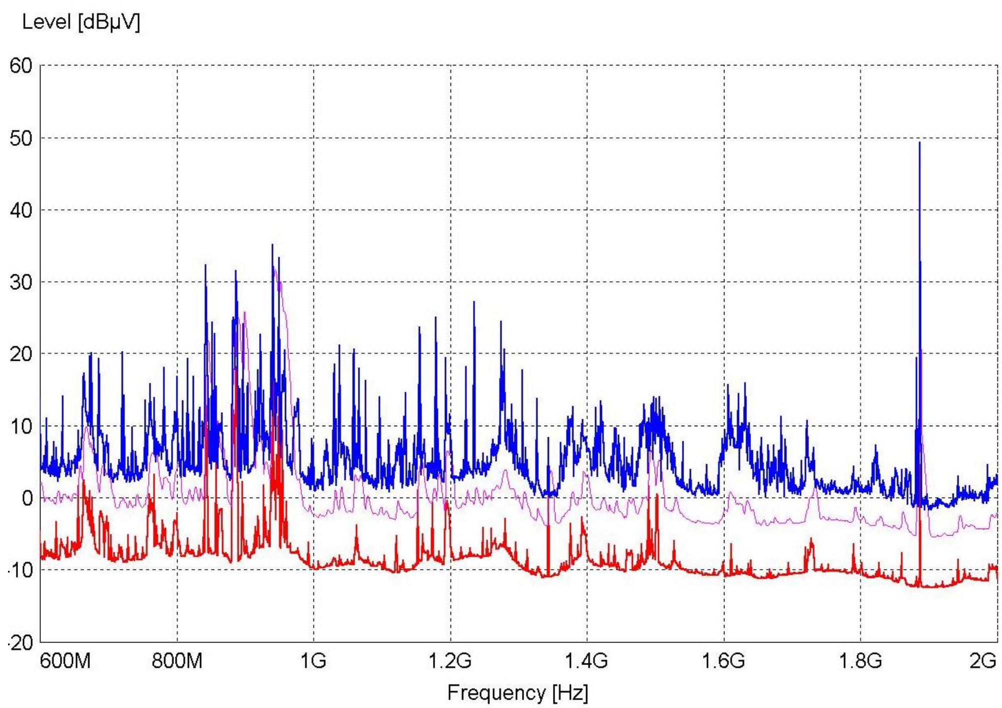

Figure 4.38: Scan Graph showing scan at the Refect site between 30MHz and 2GHz using the dipole antenna.

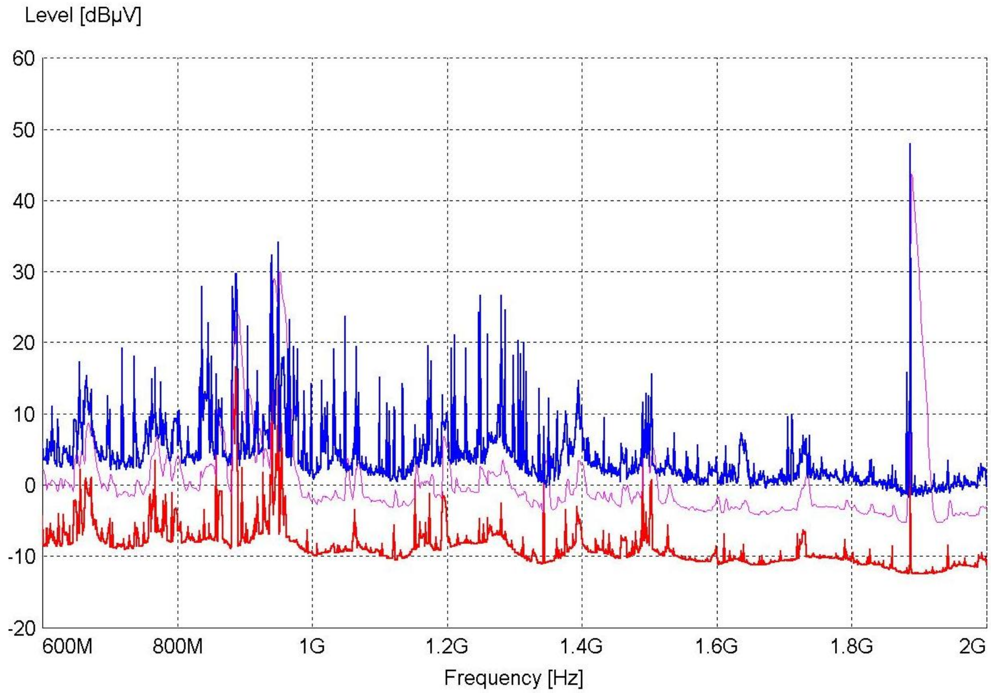

Figure 4.39: Scan Graph showing scan at the Refect site between 30MHz and 2GHz using the dipole antenna.

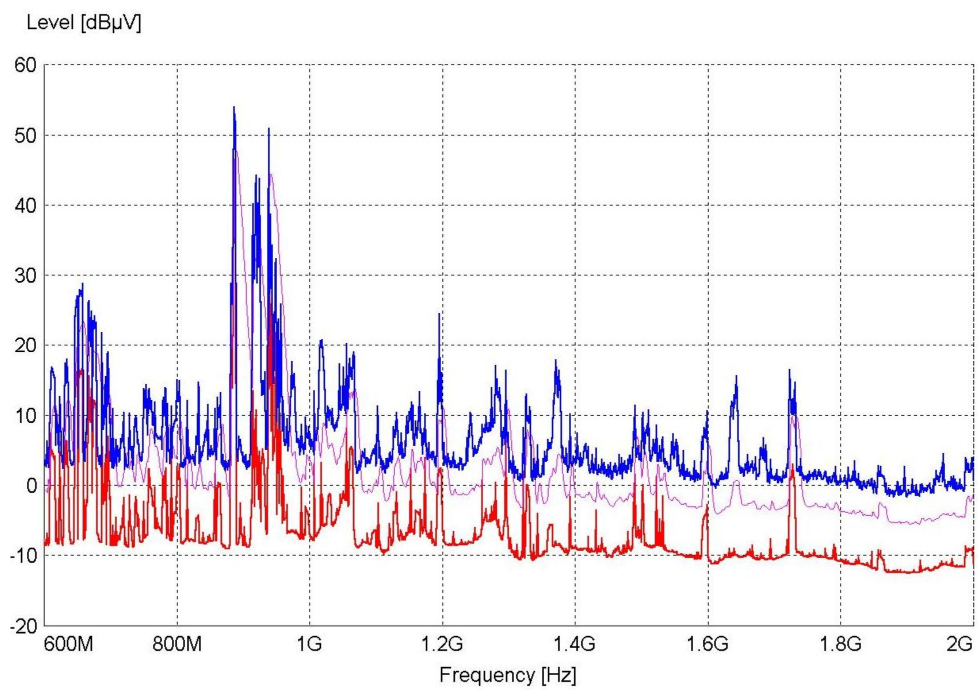

Figure 4.40: Scan Graph showing scan at the GSM Transmission Antenna site between 30MHz and 2GHz using the dipole antenna.

Chapter 5 – Project Discussion

5.1 Results Discussion

From the extensive results above there is a large amount of information to discuss.

The big question for this project is how the results compare to the standards and whether people are at risk around the university.

This project found that even the highest reading was minuscule in comparison with the standard; readings showed the worst case frequency range yielded a value of $4.166\mu W/m^2$ compared to the calculated standard $4.47 W/m^2$. The final value is less than 10^6 times smaller than the standard. This means that there is no possibility of any short-term effects of EM radiation based on the current scientific literature available today.

The signal which provided this result was the 102.7MHz; 4DDB FM radio transmitter located on the USQ campus and so was within 200m to 300m of nearly every on-campus test location.

The long-term effects of electromagnetic signals of any strength are still under question and so it could be beneficial to minimise exposure until the scientific community is sure that EM energy is safe. This means that analysis of the different amplitudes, the number of signals and the variability of these signals is important. There is a multitude of results for these topics.

In general the random nature of the signals was the main limiting factor, as quite often signals were highly variable in amplitude or at times just not present. It needs to be reiterated that this makes analysis of signals extremely hard and the only way to overcome the problem is to increase the number of samples in the hope of getting a more representative response. However, with each set of scans taking an hour with the equipment used it is highly unlikely that taking more samples would be a viable option, especially when thinking of battery life required for a number of these scans.

From the results some trends in signal strength/unit of measurement can be deduced. As previously mentioned, the highest peaks consisted of the 4DDB FM radio peak, after this were mobile phone networks and a surprising result of a Black and White Cab company signal measured at the GSM transmission antenna. This was unexplained with the possible exception of a taxi parked nearby talking to the HQ radio. This is not a plausible explanation to me so this appears to be an unknown variation.

All of the major mobile phone networks also had high peaks. Vodaphone measured the highest of all, followed by Optus and finally Telstra.

Comparisons between sites and frequencies were rather complex and hard to determine but a few key patterns emerged. The Eastern Area of the university had the highest numbers of peaks, followed by the centre of the university (besides the Refect low results) and finally the off-campus locations. Further analysis of the breakdowns has shown a high number of signals around the FM band and the 800MHz to 1GHz band with the other frequency ranges showing intermittent and rather random results which could not be concluded as providing a continual peak response.

Signal fluctuation of signals was a key feature as it provided the ability for a signal to fluctuate into higher peaks, hence providing a higher peak value than was able to be measured during the experimentation. Once again the 900MHz to 1GHz band had the highest fluctuations and this corresponded to the mobile signals which were expected to fluctuate.

The largest surprise in looking at the signal fluctuation was that there were no real patterns. The initial expectations were that same signals would fluctuate at similar ratios to its amplitude with no real dependence on the location of the site but it was found that the scans at different sites caused the results to change dramatically. One reason for this could be that the scans were all done within similar time-frames, and so similar results were obtained within each time-frame, but these similarities did not cross over and compare to other time frames at other locations. For example a television broadcast appears very similar for one 30min program but significantly different when compared to the next 30min program.

Trends that have been noted for the amplitude of the signals are that indoor areas generally seem to have slightly fewer signals and lower amplitude levels than outdoor areas. This implies that building structures provide some protection from exposure levels.

The highest exposure for a location appeared to be the GSM Transmission Antenna Site. While it did not have the highest number of peaks, the signals that were present were of higher amplitudes than most other places and the variation in these peaks was very small. This result was expected as the site is located along the roadside around 100m away from a multi-use antenna in an out of town location. These characteristics lead to having a clear line of site to a tower which is located away from the residential areas and needs a higher signal strength due to being out of town.

Signal Polarisation was another area of interest for this project. Most signals could not provide evidence as to whether the source was horizontally or vertically orientated as there was evidence suggesting both and this usually resulted in a small net bias to either orientation but not enough to make conclusions.

There were a few situations in which bias was very clear. Each of these times the bias was towards a horizontal orientation and based around the 700MHz to 800MHz frequency range. The clearest location was the Z Block laboratory. Signal amplitudes of around 50 to 55dBμV/m were found for the vertical orientation while signals of closer to 65 to 70dBμV/m were measured for the horizontal orientation and this was consistent throughout the different scans. Very similar looking results were also measured during the horizontal orientation testing of the public park but vertical orientation could not be measured at this site.

The S Block site and the Z Block oval also showed evidence of consistently higher horizontal signal bias with this 700MHz to 800MHz range but this was not as large as the Laboratory site. The conclusion that can be drawn from this is that most 700MHz to 800MHz signals are of a horizontal orientation but very few other frequency ranges can be concluded as biased to either orientation.

5.2 Experiment Discussion

Questions have to be raised as to the validity of this research. When compared to the mobile base station survey talked about in (Section 3.3.3, page 72), the experimental data of this project had maximum values of around 4.2μW/m^2 or 0.0042mW/m^2. The equivalent values from the mobile base station were anywhere from <0.001mW/m^2 to low levels at around 0.007mW/m^2 to 4mW/m^2.

The results appear to be accurate as this is in the range of the mobile base station amplitudes but it has to be remembered that the results covered a larger range of frequencies and no studies of typical values could be discovered for these other frequencies. As well as this the results are on the lower end of the measured mobile base station results which implies possible skewed values. The question that has to be answered is whether these values are low due to the location of the experimentation and the lower power output of nearby antennas or whether there is some implied inconsistencies in the equipment and measurement phase of this experimentation.

The validity of the results cannot be determined without a separate study to test this same area with different equipment to see if the same values were achieved. Without another study the validity cannot be confirmed but my thoughts are that the results are close to correct. My reasons are that many of transmission sites, which were the sources of the measured signal, were located at a distance from USQ. The major exception to this was the S Block transmission 4DDB radio antenna which is a local town antenna and so is not a high power antenna.

There were many potential problems with the experimentation of this project. One major one is the validity of the results which was just discussed. The second is the sample size. With variable signals a higher sample size is required to have a true representation of the signals but this could not be done with the current equipment.

The antenna range was also a major area of concern. The AM Radio frequency, newest mobile phone frequencies and Bluetooth frequency could not be detected with the antenna setup as it was.

Another problem with this experiment is one which applies to all EM experiments today. Even with the results that have been achieved it is still unclear as to the harmful nature of long term exposure to low-levels of electromagnetic radiation.

This is a topic of hot debate and there are numerous studies underway and completed. There is an overabundance of data published today which is hard to determine which results are credible, especially when multiple studies have contradicting results.

5.3 Future Experiment Recommendations

Recommendations for future experimentation are as follows. Another independent group using different equipment would help prove or disprove the validity of this study's results, as stated above in (Section 5.2, page 113).

Future experimentation with this equipment would be worth while. Testing of a larger sample size over a month, rather than a week, would reduce the variability of the signals and so produce more accurate overall results. This longer experimentation would require a revision of the battery situation for outdoor purposes as two and a half hour batteries would be insufficient. Also more locations could be included such as public sites downtown and the television broadcasting sites on Mount Lofty, in North Toowoomba.

Extending the range of the antennas would be of great benefit to any future experimentation. The ability to measure up to 3GHz rather than one would include a very large amount of extra data and would include the technology range which is up to date with 3G networks and Bluetooth wireless communications. This only requires the recalibration of the current Ultralog which could be completed in any span of time from a few days to a few weeks, and could be completed by USQ staff for future student projects.

Lastly the measurement range could be lowered down to the AM radio band. The AM radio band is older technology with variable amplitude and it is common knowledge that AM radio antennas have to run at a much higher power than FM for these reasons. It is believed that often AM radio is close to the standard restrictions near the site, ie, just under the antenna or at the fence if it is fenced off. This testing would need to be done at an AM radio site and would not provide much extra information towards the project besides the AM frequency band and whether it conformed to the Australian Standards. With the possibility not meeting standards it could be a major part of this project.

Chapter 6 - Conclusion

This study found that there is almost no risk of any exposure of unsafe levels of EM radiation to the general public. The results for EM readings at the test locations were 10^6, or around one million, times lower than the Australian standards.

The highest recorded frequencies for this study were the 102.7MHz signal, which was concluded to originate on top of a building on campus from licensing information. This was the highest consistent value measured.

Also three separate mobile phone frequencies of 910MHz, 904MHz and 888MHz were also high peaks, each being found to correspond to a different mobile phone network. And one last high peak of 923MHz was measured, which was believed to be the signal frequency for a taxi radio system in the area.

The measured values often had variable amplitudes changing over time. This implies that all of the signals that were measured might not represent the true values, but with a larger sample size would give an accurate representation. A 40 per cent variation for one signal at one site was found and so all measured peaks may in fact be higher or lower on average.

Although the literature remains inconclusive as to whether there are long-term risks associated with exposure to low levels of electromagnetic radiation. From the studies which were analysed it appears that the risks of long-term EM radiation effects are much lower than most people fear. There may be a few effects from the electromagnetic radiation but the study conducted in Denmark seems to provide the best evidence that there is no correlation between EM radiation and cancer.

However to reduce any possible long-term risk that there may be, indoors areas appear to have lower EM exposure, with the canteen area, on ground floor under the campus library in the centre of the university, showing lower overall exposure, despite having the highest mobile phone peak exposure value.

Appendix A – Project Specifications

University of Southern Queensland
Faculty of Engineering and Surveying

ENG4111 / 4112 Research Project
PROJECT SPECIFICATION

FOR: Simon Paech
TOPIC: Human Electromagnetic Radiation Exposure
SUPERVISOR: David Parsons
ENROLMENT: ENG4111 – S1, E, 2008
ENG4112 – S2, E, 2008

PROJECT AIM: This project is to measure the strength of electromagnetic fields around a typical office workplace and in the outside community and to relate the results to the regulations governing human exposure and to the medical epidemiological studies.

PROGRAMME: **Issue A, 26 Mar 2008**

1. Research relevant information on the topic of Electromagnetic Radiation and Exposure. This will include:
    *EM (Electromagnetic) Radiation in general and relevant frequency ranges
    *EM Radiation effects on people
    *Causes of EM Radiation
    *Electromagnetic Radiation Standards such as safe exposure levels, distances and similar statistics
    *Some examples of community perceptions of the health risks posed by electromagnetic radiation.

2. Develop a methodology for measuring human radiation exposure by reference to published studies on similar topics.

3. Perform electromagnetic radiation measurements in a range of real environments to simulate the electromagnetic exposure of occupants and of the public.

4. Analyse the data collected and perform calculations on the data to provide useful information, and compare with published information.

5. Draw conclusions and make recommendations about the appropriateness of the current regulations or about community perceptions.

Appendix B – Project Selection Description

08-070 Human electromagnetic Radiation Exposure

Topic reference number: 08-070

Title: Human Electromagnetic Radiation Exposure
Originator: David Parsons
Available for Major/s: Electrical
Sponsor: Faculty of Engineering and Surveying

The level of radio frequency electromagnetic radiation is regulated by authorities around the world in order to ensure people are not exposed to excessive levels. In Australia regulation is done by the Australian Communications and Media Authority which issues guidelines about levels and how to assess them. At the same time there are medical studies being done to continually re-assess the health impacts of these fields.
This project is to measure the strength of fields around the USQ workplace and in the community and to relate the results to the regulations and to the medical epidemiological studies. Examples of locations where measurements could be taken are:

- Typical USQ office with PC
- Next to mobile phones and to mobile phone base stations
- Various electrical/electronic equipment around USQ – concentrations of PCs, copying machines, etc
- Local radio or TV broadcasting towers etc

Since exposure regulations are concerned with radiation level and time of exposure, and since radiation levels probably change over time, there will be a need to collect significant data and to analyse it statistically. Software and equipment is available to allow the automatic collection of this data.

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