INVESTIGATION OF COHERENT SIGNALS IN WATER

by

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This study deals with hypothetical and experimental considerations in respect of water which has been "treated" with magnetic fields, and with substances which have been serially diluted in water beyond Avogadro's constant.

A review of the relevant literature concerning changes in the physical properties of "treated" water is given, with particular reference to the relations between the physical properties and molecular structure.

The properties of water are reviewed in terms of the molecular structure of the liquid especially at its interfaces with metal electrodes and with biological cells.

An enclosure adequately free from electric and magnetic interference has been designed and built. Its performance has been calculated and experimentally verified with especially designed and constructed instrumentation.

Following this, the design and construction of an ultra-low-noise, high input-impedance, and low-drift amplifier for detecting weak coherent signals thought to be involved in "treated" water. The main transducer system used for this amplifier was a pair of gold wire electrodes immersed in the water sample for which the electrical characteristics were to be measured.

Suitable experiments were developed for the evaluation of particular theories relating to "treated" water and for the
detection of weak signals which might result from coherent oscillations in water over the VLF part of the non-ionizing frequency spectrum.

In the course of this work, spectra of coherent oscillations and acoustic absorptions were obtained from water "treated" magnetically (ie exposed to specific frequency magnetic fields) but, the complete understanding of the exact physical fundamentals involved will involve considerably more work both theoretical and experimental.
DEDICATION

Αφιερώματα στους γονείς μου
Αναστάσιος και Ζωή Τσούρης.

Dedicated to my parents
Anastasios and Zoe Tsouris.

iii
TABLE OF CONTENTS

ABSTRACT i
DEDICATION iii
TABLE OF CONTENTS iv
ACKNOWLEDGMENTS viii
GLOSSARY ix
INTRODUCTION 1

Chapter I. Historical Review
1.1 General Introduction 5
1.2 Properties of Potentized Water 7
   1.2.1 Introduction 7
   1.2.2 Biochemical Effects 8
   1.2.3 Physical Properties of Potentized Water 10
   1.2.4 Physical and Clinical Properties of Magnetic Potencies 12
   1.2.5 Analytical Chemical Investigations 15
1.3 Review of the "Memory Mechanism of Water 17
1.4 The C.W. Smith Hypothesis 19
1.5 The Vithoulkas Hypothesis 21
1.6 The Del Giudice Hypothesis 22
1.7 The Preparation of Homoeopathic and Magnetic Potencies 24
1.8 Potentization with a Magnetic Vector Potential 26
1.9 Inactivation of Potentized Water 27

Chapter II. Properties of Water
2.1 Introduction 28
2.2 Properties of Water 28
2.3 Quantum Field Theory Approach to Water
2.4 Vicinal and Interfacial Water
2.5 Acoustic Properties of Water

Chapter III. Electric and Magnetic Shielding
3.1 Introduction
3.2 Shielding Theory
3.3. Circuit Theory Approach to Shielding Effectiveness
3.4 Measurement of Shielding Effectiveness
3.5 Results
3.6 Comments
   3.6.1 Comments on the Calculation of Shielding Effectiveness
   3.6.2 Comments on the Measurements of Shielding Effectiveness

Chapter IV. Low Noise Instrumentation
4.1 Introduction
4.2 Low Noise Amplifiers
   4.2.1 Physical Properties of Noise
   4.2.2 Low Noise Design
   4.2.3 Noise in the Field Effect Transistors
4.3 Low Noise FET Amplifier
4.4 Measurement of Amplifier Noise
4.5 Results
4.6 Comments
Chapter V. Electrode Characteristics
5.1 Introduction 72
5.2 Electrical Properties of Electrodes 72
5.3 Measurements of Electrode Impedance 73
5.4 Results 75
5.5 Comments 76

Chapter VI. Experimental Work
6.1 Introduction 78
6.2 The Preparation of Homoeopathic and Magnetic Potencies 79
6.3 Experiment I
   6.3.1 Introduction 80
   6.3.2 Method 80
   6.3.3 Results 82
   6.4.3 Conclusion 83
6.4 Experiment II
   6.4.1 Introduction 83
   6.4.2 Method 83
   6.4.3 Results 84
   6.4.4 Conclusion 85
6.5 Experiment III
   6.5.1 Introduction 85
   6.5.2 Method 86
   6.5.3 Results 86
   6.5.4 Conclusion 87
6.6 Experiment IV
   6.6.1 Introduction 87
   6.6.2 Method 87
6.6.3 Results

6.6.4 Conclusion

Chapter VII Discussion

Conclusion

Appendix I

Appendix II

References
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This thesis has been written in order to fulfill the requirements of the University of Surrey for the award the degree of Doctor of Philosophy as specified by the regulations of the University.

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viii
GLOSSARY

Activated water: means potentized water. (q.v.)

Allergy: the term allergy was coined by the Austrian pediatrician, von Pirquet, from the Greek words 'ALLOS' = change and 'ERGON' = action. It describes a state of altered reactivity on exposure to a specific environmental factor. It is often used in the more restricted sense to refer to the subset of allergic patients who have abnormal immunoglobulin-E antibody effects.

Avogadro's number: This is the number of molecules needed to make up one gram-molecular weight of any substance, it has the value $6.02 \times 10^{23}$ molecules.

Boltzmann's constant: is the GAS CONSTANT divided by AVOGADRO'S NUMBER, it relates to the energy per degree absolute of temperature.

Coherence: the existence of definite fixed relationships between the phases of otherwise separate waves makes them coherent. It is a measure of the degree of precision of the velocity, frequency and wavelength.

Hall effect: is the deflection of an electric current by a magnetic field and its importance is that it gives the sign and number of charge carriers per unit volume of the conductor or semiconductor.
Hypersensitivity: A state of increased sensitivity to environmental agents. Allergy is a hypersensitivity to particular chemical or biological allergen. Physical hypersensitivity can arise from acoustic noise, high temperature and electromagnetic radiation for example.

Josephson effect: occurs at a weak-link junction between two superconductors and is associated with quantised magnetic flux. It provides an interconversion between frequency and voltage.

Magnetic potency: a potency which has been prepared in the presence of a magnetic field.

Memory: The term memory is defined herein as some property of a liquid or solid whereby it can change in one or more of its physical properties after undergoing a particular treatment.

Mother Tincture: is a substance which has undergone a very specific treatment and has reached the form where it can be potentized.

Potency: A liquid (usually water) which has been treated to give a therapeutic property. A potency also denotes the number of serial dilution (and succussion) in the preparation of the remedy.

Potentized water: The term potentized water, is defined in this thesis as water which has undergone a very specific treatment involving serial dilution and succussion, or exposure to magnetic field and succussion.
Succussion: this the process where a solution is subjected to strong impacts against a hard surface.

Treated water: means potentized water.
INTRODUCTION

This work was initiated on the basis of information contained in a scientific commercial report published by the German physicist W. Ludwig (1988) regarding the detection of weak coherent signals in homoeopathic remedies thought to be a result of coherence in the medium which is usually water based.

Smith C. (1985b) had already demonstrated the clinical effects of both serially diluted allergens and of water "treated" with magnetic fields on hyper-sensitive people. From this, it was evident that homoeopathic remedies, serially diluted allergens and water "treated" with magnetic fields must share the same mechanisms not only for the storage of bio-information but, also in the way in which they act upon living biological systems.

Homoeopathy is a form of alternative medicine method for treating / curing disease. The fundamental difference from orthodox medicine is that a particular remedy prescription is based on the holistic symptom pattern of the patient and not on the diseases of the subsystems. The remedies are characterized through the so-called proving symptoms which develop in a healthy person who takes a remedy and which matches the symptoms of the illness for which a particular homoeopathic potency is regarded as therapeutic. Thus, the homoeopathic remedy is prescribed to a patient having the same symptoms as the proving patterns of the remedy (Vithoulkas, 1990). The remedies are usually prepared in distilled water or alcohol, where a substance is diluted with the solvent in a sequence of serial dilution and succussion. The serial dilutions may exceed Avogadro's constant \( (6.02 \times 10^{23}) \), at which case the solution will not include a single molecule of the initial substance.
The objective of the present work was to repeat Ludwig's experiment (Ludwig, 1988) by detecting coherent signals involved in homoeopathic remedies and in water which has been "treated" with alternating magnetic fields of known frequency. This latter allowed the critical assessment of all measurements since a known frequency imprint had to be measured correctly.

An investigation into the properties of both homoeopathic remedies and magnetically "treated" water is the starting part of this thesis. It followed a comprehensive review of relevant work already published on this subject (Tsouris, 1991). There were five areas of interest; a) the physical properties of the "treated" liquid, b) the biochemical effects of the liquid, c) the physical properties of magnetically potentized water and d) the analytical chemical investigations on treated water. The last area of interest includes the theoretical considerations given to potentized water in terms of the possible molecular structures which the water might sustain in order to store the bio-information imprinted into it.

Water has been investigated with special reference to its physical properties and their relations to its molecular structure, the properties which characterize liquid water as well as the flexibility and versatility of its structures and its ability to store bio-information. The suggested possibility of some form of crystalline structure in liquid water has been reviewed in terms of possible ionic defects similar to those which are present in ice. Water has also been investigated when it is at the vicinity of other substances, and particularly when inside or close to biological cells.

Since water which is "treated" with magnetic fields is
investigated, the experimental environment for these investigations had to be controlled and so the work began with an electric and magnetic field free environment. The design and calculation of the characteristics of high performance shielding enclosures is given with particular reference to very low frequency (VLF) electric and magnetic shielding which is the region where the signals of interest were expected. Suitable instrumentation was designed and constructed and test procedures for measuring the shielding effectiveness of the enclosures constructed were devised. This involved the design and construction of an AC and DC magnetometer and the development of special coil-structures which could create magnetic field patterns suitable for measuring the shielding effectiveness of the enclosures as a working entity.

The transducers used for this work were gold wire electrodes so, water has also been considered in terms of metal interfacing with water. The reason for this was the particular structure which gold can take when in contact with an electrolyte. The electrical parameters of these electrodes were measured and consideration was given to the various possible noise sources involved at the electrode-electrolyte interface and to the effect of mechanical fluctuations which could result in weak signals being induced at the electrodes.

The signals from the water through these electrodes were investigated with an ultra low noise amplifier which was designed and built specially for this purpose after an investigation had been made into the characteristics of the low noise devices available on the market, and the noise associated with various discreet semiconductor components. The design details of this ultra low noise amplifier include considerations of its ability to
work at virtually any source impedance, including electrodes in contact with water, capacitive and inductive impedance sources.

Practical experiments for detecting weak signals in water were devised from the theoretical models of water and from considerations of the apparatus used for the investigation of water by other workers. There were three main classes of experiments: a) the detection of weak signals from water that was activated with acoustic waves both coherent and incoherent, b) the detection of signals from water activated by an alternating magnetic vector potential and c) the detection of coherent signals in water which was not under any intentional excitation.
CHAPTER I

HISTORICAL REVIEW

1.1 GENERAL INTRODUCTION

This chapter gives a historical review of phenomena in water with special reference to "memory" effects which have application in homoeopathic remedies prepared in water. These "memory" effects are reviewed in terms of changes in the physico-chemical properties of the liquid originating from both homoeopathic sources and from experimental and theoretical physics.

Since the beginning of homoeopathy in the 19th century, homoeopaths have looked for evidence of "memory" phenomena in water capable of giving the clinical effects corresponding to the substance which had been near-infinitely diluted with the solvent in a sequence of serial dilution and succussion. Physicists have looked for changes in liquid water after being exposed to time-varying magnetic fields. Both studies have been stimulated by the observed biological or clinical effects which characterize the potentized liquid when tested on living organisms.

The term "potentised water" is defined in this thesis as water which has undergone a very specific treatment involving serial dilution and succussion (exposure to a mechanical shock wave). The term "memory" is defined here as some property of a liquid whereby it can change in one or more of its physical properties when undergoing a particular treatment.

In homoeopathy, water is activated or potentized when a substance is serially diluted with water, each dilution being followed by succussion. The serial dilutions are usually made
volumetrically by a factor of ten or hundred. The number of these operations are denoted by the number and the symbol X or D for ten and C or CH for a hundred (Vithoulkas, 1980). After each serial dilution succussion follows, it consists of 10 to 100 strong impacts of the phial or glass tube containing the solution on a hard surface such as wood, although traditionally this was done on a leather bound book.

Potencies prepared with magnetic fields which are referred to herein as "magnetic potencies" are prepared in the presence of an alternating magnetic field or alternating magnetic vector potential plus either a static magnetic field or succussion in the presence of the particular frequency which is to be imprinted. Serial dilutions of a magnetic potency may be performed subsequently.

In the field of materials science, many substances show changes in their physical properties according to the history of treatments which they have previously undergone. In the following paragraphs, a brief review is given of those "memory" properties of different materials which arise according to their treatment.

Copper gives different thermochemoluminescence energy according to the previous treatment which it has undergone. In addition, the oxidization rate of copper alters proportionally to milling treatment received (Resch and Gutmann, 1987). Other metals acquire shape memory properties as a result of heat and mechanical treatment. A typical material having a shape memory effect is the alloy consisting of 50% titanium, and 50% nickel which, when forced into a desired shape at a particular temperature will recover that given shape when subsequently exposed to the same temperature.
Similar "memory" properties are found for ice. Studies on phase transformations in ice showed that specific crystalline structures of ice formed under different pressures and temperature would reproduce when the ice was heated and recrystallized (Bridgman, 1949).

Osada and Yosaki (1985) developed a mechano-chemical valve with a mixture of water and gel. In this experiment they found switching and memory phenomena in water containing organic materials similar to those originally found in certain metal oxides and amorphous semiconductors.

Resch et al. (1982) investigated the conductivity of NaCl dilutions in water. They observed that the conductivity of the solution changed if the sample had been succussed between dilutions. This experiment implies that succussion changes some of the physical properties in water.

1.2 PROPERTIES OF POTENTIZED WATER

1.2.1 INTRODUCTION

The "memory" properties of water have been under investigation since the beginnings of homoeopathy. The research has been directed mainly by medical doctors and by scientists closely related to medicine for the express purpose of establishing and standardizing the tools of their profession in alternative or complementary medicine. In this section, a review of the research done by homoeopaths is given with particular reference to the action and influence of the homoeopathic remedies
on biological systems, and various analytical chemical methods used to identify changes in the physical and chemical properties of the remedies. The most recent work by Reilly et al. (1994) concludes that homoeopathy differs from placebo in an inexplicable but reproducible way.

The following studies described, mention a change or variation of a particular quantity in potentized water which seems to vary in a fluctuating fashion. Specific changes in one direction or another, are only given, if specified by the author. In other case, the term "change" usually implies a variation in activity which fluctuates with the potency.

1.2.2 BIOCHEMICAL EFFECTS

In 1930, Persson investigated potencies of mercuric chloride up to 120X for their effect on the fermentation of starch by salivary amylase and on the lysis of fibrin by pepsin and trypsin. Significant results were obtained and clearly showed the effect of different potencies. The most important study on the biochemical effects of potentized water was carried out by Boyd (1954). This outcome of fifteen years research was published in two homoeopathic journals and a British newspaper. Potencies of mercuric chloride were used to study the rate of hydrolysis of starch with the enzyme diastase. The control flasks had starch diastase and distilled water only. They were compared with flasks containing the same substances plus mercuric chloride at the 61X potency. The rates of hydrolysis were studied colorimetrically with an absorption meter. The experiment showed that mercuric
chloride potencies accelerated the rate of hydrolysis in more than five hundred comparisons.

Jussal (1984) performed experiments involving homoeopathic remedies and enzymatic reactions. Specifically, the activity of acetylcholinesterase was investigated under the influence of arsenic potencies. The results showed a very clear indication of a change in the reaction rate under the presence of the potencies when compared with the control flasks. Further experiments with enzymatic activities led to the development of a new method of diagnosis based on blood samples which are tested for different enzymes under the influence of homoeopathic remedies (Jussal, 1984).

A team of thirteen scientists from all over the world in a study co-ordinated by Prof. Benveniste published their work on the biochemical action of potentized water (Poitevin et al., 1988; Davenas et al., 1988). For the experiment they used human basophilis with attached antibodies of the immunoglobulin type E (IgE) on their surface and potencies from 20X to 120X of anti-IgE. The results clearly showed the effects of the potency and were repeated in different laboratories around the world. The same results were obtained even if the solutions were passed through a molecular sieve in order to demonstrate that not even a single molecule of the original substance in the potency remained and that the cause of the effect must be in the solvent. However, the results failed to repeat to their own satisfaction when a team from the Journal "Nature" visited Prof. Beveniste's laboratory in order to verify the results once more.
An extensive review of bacteriological, botanical, and zoological effects of homoeopathic remedies has already been carried out in a previous work by the author (Tsouris, 1991).

For the treatment of human illness, there are a number of Materia Medica written and recent reports from homoeopathic institutions show that about 90% of the today's illness could be cured with homoeopathy (Vithoulkas, 1990). The possibility remains that potentized water is able to activate all forms of life, no matter what size and complexity. Furthermore, due to the wide varieties of ways in which potencies can be applied to biological systems, eg. orally, injection, inhalation, and through the skin, it implies that living systems must all share a common way of decoding this bio-information which is carried in a potency and be able to respond to it effectively. To sustain life in a biological system, bio-communication and coherence within the system are essential. This is one of the main factors that all living systems share in common.

1.2.3 PHYSICAL PROPERTIES OF POTENTIZED WATER

The first scientific research on the physical properties of potentized water was carried out by Wursumser in 1948 (Stephenson, 1955). The light absorption from different potencies was investigated with reference to a luminous source of fixed wavelength. The transducer was a photoelectric cell which detected differences in the intensity of the incoming light after it had passed through different potencies.

Ansaloni and Vecchi. (1989) detected similar optical density
changes in water which had been potentized by biohealers. Gay in 1951 detected anomalies in the dielectric constant of potentized water. In 1953, he extended this work in collaboration with Boiron when using the same apparatus they were able to distinguish flasks containing sodium chloride in 54X potency from six other similar flasks containing only distilled water. When the results obtained for the dielectric constant were plotted against the serial dilution number they found to vary in a fluctuating fashion (Stephenson, 1955).

The dielectric constant was also measured by Smith C. et al. (1985a) for magnetic potencies. Water was potentized at 50 kHz in a magnetic field and the dielectric constant was found to be different from that of the untreated water at 50 kHz ± 10 Hz. These measurements were made with a capacitance bridge.

The dielectric constant was also investigated by Jussal et al. (1983) for alcohol based potencies. These potencies were made according to a logarithmic scale (base 10) and changes in capacitance were detected as a function of both the potency and the frequency used for the measurements with a capacitive bridge. Hadley and Pharh (1981) made an effort to repeat this determination of capacitance variations in homoeopathic remedies. They detected a phase shift in the test signal which varied according to the potency.

Jussal (1984) detected a potential difference in the millivolt range across two electrodes immersed in a Barium Bismuth Carbonyl solution in water. The voltage was found to vary in a fluctuating fashion according to the potency dilution.

Kumar and Jussal (1985) investigated the surface tension of alcoholic Natrium Muriaticum potencies from 6 C up to 30 C. The measurements involved the determination of the rise of the liquid
in a fine capillary tube and the values were compared with the rise of dispensing alcohol in the same capillary tube. The ratio of the two measurements gave the ratio of the surface tension of the potency to the surface tension of alcohol of the same purity. The experiments took place in a temperature controlled environment. The measurements were made with a travelling microscope. The results showed that the surface tension varied in a fluctuating manner according to the potency and showed distinct maxima and minima at certain potencies. It was found that the second maximum occurred eighteen potencies after the first maximum and the minimum occurred nine potencies after the first maximum.

The dielectric strength test on mercury chloride potencies showed that the dielectric break-down strength of the remedies is different than that of pure water, and varies according to the degree of potentization (Brucato and Massachusetts, 1966).

A different approach to display the action of potentization was taken by Kumar and Jussal (1979), who used lactose pellets soaked in a potency to display a change in the structural arrangement. Potencies from 10C to 120C were used and each potency showed specific structure formations were taken up by lactose.

1.2.4 PHYSICAL CLINICAL PROPERTIES OF MAGNETIC POTENCIES

Studies on supercooled water exposed to an alternating magnetic field have shown that the orientation of the crystal structure of the ice formed depends on the direction of the magnetic field. The frequency of the magnetic field was in the kHz region. The crystal orientation was frequency dependent and
independent of the temperature of crystallization. The orientation of the crystals were also found to be independent of the magnetic field exposure time and the magnitude of the magnetic field only altered the density of the alignment (Jaberansari, 1989).

Piccardi (1950), was the first to investigate cosmic influences on colloidal solutions and water. These were exposed to alternating magnetic fields at frequencies in the kHz range which occur in the environment.

Studies by Mu-Shik (1986) have shown that mixtures of salt and water exposed to a static magnetic field have altered the surface tension. The surface tension was found to be dependent on the substance present in the solution and the magnetic field strength. Presmann (1979) found anomalies in dielectric constant and changes in the light absorption in water exposed to static magnetic fields of the order of 1 mT.

According to Presmann (1979) experiments on the biological effects of water exposed to magnetic fields date back to 1965. Experiments with mice and pigs receiving only water exposed to frequencies in the kHz region, showed increase in weight in comparison with control animals receiving ordinary water. The effect of water "exposed" with a static magnetic field on seedlings of sunflower, corn, and soybeans showed acceleration in the rate of growth, increase in height, and thickness of the plant in comparison to control samples which were treated with pure water (Presman, 1979).

Smith C. et al. (1985b) demonstrated the clinical effects of potentized water on certain hyper-sensitive people with certain allergies. Water potentised at a particular frequency could activate the allergic symptoms of a patient, and water exposed to another particular frequency, specific for the patient, could
neutralize the allergic symptoms.

Thus, water seems to be able to "remember" the frequency or frequencies it has been exposed to. The frequency range over which water has been potentized and tested on hyper-sensitive people ranges from mHz to GHz. The clinical effects have shown no limit as to the number of different frequencies one can potentize into a single water sample, and samples with up to 500 different frequencies have been prepared.

There is a minimum field strength required for water to become potentized and it depends on the particular fields used (Smith C., 1992) (see section 1.8).

Water potentized with a stronger field strength does not show any enhanced effect on allergic persons which clearly indicates that water imprints are an all-or-nothing effect.

The biological system appears to be involved in the decoding of the bio-information imprinted in the liquid. This can be demonstrated when a hyper-sensitive person has reactions when activated on exposure to a particular frequency of magnetic field or when these are neutralized with a particular potency of chemical allergen, which can either be given orally, topically or by injection (Smith C. and Best, 1989) as an alternative to neutralization by a frequency. An allergic patient may develop reaction symptoms to more than one frequency. The frequencies to which one person is allergic, have no correlation with those to which another is sensitive, that is to say every allergic patient reacts characteristically for a particular frequency or set of frequencies. Similar reactions and suppressions of symptoms have found with homoeopathic remedies and magnetic potencies. In the Organon of Medicine (Hahnemann, 1983) written in 1810 by Samuel Hahnemann the founder of homoeopathy, it is mentioned that
homoeopathic remedies can be made by static magnetic and electric fields. Remedies can be specifically prepared on the South pole of a magnet, the North pole of a magnet, or between the two poles of magnet. Smith C., (1991) has shown through clinical effects that one can also potentize water with a magnetic vector potential whether produced with a magnetic field in a coil, or solenoid, or through a toroidal transformer. He considers that the bio-information is carried on the magnetic vector potential and that succussion or a static magnetic field formats the water to accept this bio-information.

These studies suggest that the treatment of water with magnetic fields similarly causes changes in physical properties as are evident in homoeopathic potencies.

1.2.5 ANALYTICAL CHEMICAL INVESTIGATIONS

A number of researchers have studied potentized water by analytical chemical methods in order to express the action of the different potencies in terms of the alterations in the chemical and molecular structure of the liquid. In this section, an overview of the analytical methods used to investigate the homoeopathic remedies and magnetic potencies is given with particular reference to structural changes found in potentized liquids.

Kahan (1985) studied the ultraviolet spectrum of Aconite in potencies 1X to 300X. He observed significant changes in the spectra of the potencies which enable him to make comparisons between the same drug prepared by different pharmacists. Similar
observations and comparisons for different potencies where made using an infrared spectrometer. Once more, the results obtained were very significant, and the technique was proposed for standardizing different pharmacopoeias (Kahan, 1985).

Further analytical chemical methods involve those of nuclear magnetic resonance (NMR). Smith R. and Boericke (1968) used NMR to identify increased area in the hydroxyl region of the spectrum using different potencies. The investigated potencies of Biadykinin Triacetate were made up in distilled water.

Similar changes in the hydroxyl region were also found by Boericke and Smith R. (1966) who used sulphur potencies in his experiments. The N.M.R spectra were compared with sulphur dilutions (unsuccussed), which showed insignificant changes in the N.M.R spectrum, while sulphur potencies (succussed) did show significant changes. Furthermore, ultrasonic potencies prepared by the use of ultrasound instead of succussion, displayed spectra different from those of the traditionally made potencies (Boericke and Smith R., 1966). Other N.M.R studies carried out by Boericke and Smith R., (1966) showed that by adjusting the ultrasound frequency and amplitude, the N.M.R spectrum of a potency could be the same as that of a traditionally made potency.

Sacks (1983) verified the N.M.R spectra found in the hydroxyl region by Smith R. and Boericke, (1968) using a modern high resolution spectrometer.

Anagnostatos and Viras (1992) have investigated homoeopathic remedies with a differential scanning calorimeter. Water which has become associated with some form of order-structure can have different thermodynamic properties and absorb more heat before disengaging as temperature increased. From these results, it is evident that more order and more bonded molecules are present in
potentized water than in ordinary unpotentized water.

In order to cross-check his results, homoeopathic remedies and water which had been succussed and serially diluted to the same degree of the corresponding potency were measured with a differential scanning calorimeter. The controls were just like a remedy but initially containing no mother tincture. In this way, all contaminants or experimental artifacts which could be involved in the experiment were equalized. The output of the differential scanning calorimeter was found to be a function of the particular mother tinctures involved.

1.3 REVIEW OF THE "MEMORY" MECHANISM OF WATER

The most widely accepted model for the structure of potentized water was proposed by homoeopaths. This assumes the formation of a stereoscopic isomeric structure in water (Barnard and Stephenson, 1965, 1967, 1969). The structures taken up by the water are regarded as being similar to the stereoscopic polymerization of olefines and diolefines in water-alcohol mixtures in the presence of ionic catalysts. This structural formation in water is supported by the fact that there are monomeric unbonded solvent water molecules which can be bonded together forming clusters of variable size in water. When an ionic substance is introduced into the solvent, a group of solvent molecules in the vicinity of the solute molecule interact with it and undergo transitions from higher to lower energy levels in order to achieve a minimum energy state in which the group of molecules adopt a closely packed stereospecific arrangement. In
order to meet the energy requirements of the interactions, it is assumed that an isotactic polymer chain is formed from an association of solvent molecules. In order to have the best possible packing arrangement, the structure must have a helical shape. All the monomeric units are equivalent, and the stereospecificity lies in the bond length and orientation of each molecular unit.

Each stereoregulated solvent polymer has a particular structure form of its own, and therefore many different overall configurations are possible for the many different solute molecules. The stability of such a polymer would vary from one configuration to another according to the threshold energy requirements of the interaction which is determined by all the secondary forces for all the atoms or molecular groups in the chain. Therefore, it is assumed that a particular solvent polymer must carry precise information as to the energy levels in each particular solute molecule.

The expected polymer lifetime depends on two energies; a) the minimum energy difference \( (W) \) necessary to effect a change of state and the \( kT \) energy of thermal motion where \( K \) is the Boltzmann constant and \( T \) the absolute temperature. The likelihood of a change of state depends on the ratio \( \frac{W}{kT} \). The expected lifetime "\( t \)" can be calculated as follows:

\[
t = Y \exp \left( \frac{W}{kT} \right)
\]

where \( Y = 10^{-10} \) to \( 10^{-14} \) sec.

Taking \( Y = 5 \times 10^{-14} \), and \( W = 1.15 \) eV, the expected lifetime is 8 days at 30 °C; while for \( W = 1.45 \) eV, \( t = 2000 \) years.

The polymers are assumed to be equally stabilized by the
process of succussion, which is regarded as the process of frictional electrification of water and a pump providing a supply of energy. However, a limit on the length of polymerized chain is set so that beyond a certain length, the chain would be ruptured by succussion. So, at high potencies there would be many ruptured chains of the same average length in a remedy.

The analytical chemical methods which support this hypothesis mostly involve N.M.R, these repeatedly find an increase in the O-H part of the spectrum (Smith R. and Boericke, 1966). Other studies such as Raman spectroscopy also support the existence of helical structures in water (Boiron, 1976).

1.4 THE C.W.SMITH HYPOTHESIS

The helical structure proposed by Barnard and Stephenson (1965) for potentized water it was also suggested by Smith C. et al. (1985b) but it was derived and justified through the memory properties of water which had to be able to couple to a magnetic field and represented a completely different approach.

In this case the helix structure in water is based on the pentagonal rings which are also formed in ice. It had been found in clinical work that the "memory" properties of magnetic potencies and their clinical effectiveness are retained when the liquid is frozen (Smith C. et al. 1985b). The bond angle of protons in water molecules in vapour state is 104.5°, so the fifth molecule of a pentagonal ring would be 17.5° off the 360° required for the ring to close. If the last molecule combines through a hydrogen bond to another such ring, then a helix can be formed with 0.4nm diameter and with a pitch of 0.25nm as shown in Figure 1.1 (from Smith C. et al., 1985b). The life-time of the hydrogen
Figure 1.1. Molecular model for the helical structure in potentized water. Redrawn from Smith C.W. (1985b).

Figure 1.2. Possible cluster formation in potentized water. Redrawn from Jaberansari M. (1989).
bond is of the order of $10^{-11}$ seconds, while from infra-red spectra the vibration frequencies in water are in the order of $10^{-14}$ seconds. Thus the system has ample time for the forces from coherent oscillations to align and join sections of the helix together for a "long and resonant life". This model is also found to be stable against thermal diffusion.

If the coherence of the frequencies is high enough then superconductivity type phenomena become available. These would include magnetic flux quantization which is the minimum magnetic flux that can exist (Smith C. 1985b). A helix of flux rope length 63nm would be required, ie 252 such rings linked together. However, for the water to remember a frequency of 17 mHz an $8 \times 10^8$ m long rope of coherent water helices would be required which would involve all the molecules in a 1ml volume of water.

Jaberansari (1989) showed that in supercooled water, magnetic potencies could form dodecahedron clusters as shown in Figure 1.2. This is consistent with N.M.R studies carried out by Smith R. and Boericke (1968) on homoeopathic remedies which are shown in Figure 1.3 (from Smith R. and Boericke, 1968). Such chains could still provide helical paths through their hydrogen bonds providing coherent hydrogen bond hopping along the helix structure (Smith C. 1991) as a possible way of storing a frequency in a dynamic memory.
Figure 1.3. Water group forming a hexakaidecahedron formed by 28 molecules. Redrawn from Smith R. (1968).
1.5 THE VITHOULKAS HYPOTHESIS

Vithoulkas et al. (1988) modelled the memory mechanism in water on certain cluster formations produced in water during the process of dilution and succussion for the potentization of the solute.

Specifically, he assumes that at the first stage of potentization, small clusters of water surrounded an ionic cluster. The shape of the cluster is assumed to be similar to the usual hydrophobic cluster formed in water, which is limited in size to the order of a few tens to a few hundreds of atoms. The clusters are formed by hydrogen bonds and are of specific shapes for specific ionic substances. In addition, the small water clusters are surrounded with big clusters, thus forming clathrates which include smaller clusters inside them.

During the process of succussion, the small clusters are presumed to escape from the clathrates due to differences in the inertia and a new clathrate is formed around them. However, the original clathrate now becomes refilled even in the absence of the original substance, as would be the case at infinite dilution. The clathrate can replicate its shape in each new solution. Thus, as the process of potentization continues, more and more "empty" clathrates are formed. The new cavity may not be the same size as before since this is dependent on the strength of the hydrogen bonds. In addition, a mantle-clathrate could be formed around the core-clathrate which is more organized than the replicate empty clusters. Further potentization will eventually create clathrates which have the same shape as the original substance but will be larger in size, and as the process of dilution continues their
Del Giudice (1991) and his co-workers specializing in quantum physics and particular Quantum Field Theory have been working for a long time on quantum phenomena and the superconductive properties of liquids such as liquid helium. Their theories on water, as reviewed in Chapter 2, extend to the investigation of memory phenomena in water and have special relevance to water which has been potentized or treated with a magnetic field. The Del Giudice model is based on a two-fluid liquid in which some water molecules are random as in the gas phase and the rest are in a condensed and highly coherent liquid phase.

When the number of water vapour dipoles in a given volume exceeds a critical number, a new regime is formed with the dipoles becoming coherent and oscillating in phase. They produce a coherent electromagnetic field which is time dependent and they condense to a liquid. This two-fluid model is consistent with thermodynamics if the gas phase water molecules fluctuate at random while the coherent water dipoles only interact as a coherent ensemble.

If the dipoles oscillate coherently, they appear to each other to be at rest so they could have time to attract electrostatically and establish hydrogen bonds between them. The frequency of oscillation of the dipole domain is in the order of $1.5 \times 10^{12}$ Hz \( \text{i.e.} \) a 50 cm\(^{-1}\) oscillation, each domain would be about 100 to 300 \(\mu\text{m}\) in size, involving approximately $10^{17}$ water molecules. In such an arrangement an electromagnetic wave propagating through the system would interact with the whole
domain and the velocity of the wave and the frequency of the coherent mode will be lowered. It was calculated by Del Giudice et al. (1990) that $\sqrt{10^{17}} \approx 3 \times 10^8$ molecules in a fluctuation will not break the coherence and give an electromagnetic wave velocity decrease from 300 Mm/s to 1 m/s, the coherent frequency will then appear in the kHz region ($1.5 \times 10^{12} / 3 \times 10^8 = 5$ kHz). Different sizes of coherent domains will impose different velocities and therefore different frequencies. Subsequent work by Arani et al., (1993) shows that the 12.4 eV resonance is more fundamental to water coherence and this gives the fundamental domain size as 75 nm, although the existence of larger domains as well remains a possibility.

Given enough coherence, these domains could couple to each other through the Josephson effect which depends only on the coherence established and not on the superconducting temperatures at which it is usually observed.

In order to transcribe bio-information into water, the following considerations are necessary. Firstly, the hydrogen bonds in the domain should be temporally disrupted, this may be achieved by the succussion as in the preparation of homoeopathic remedies or by a field as in magnetic potencies, and secondly, the presence of another field which can maintain order during the dilution in the water. The basic coherent internal field which keeps the coherent water molecules in phase can then change its frequency to the value of the applied field (Del Giudice, 1991).

Further publications relevant to this model have considered the bio-information involved in coherent water. This is likely to take the form of modulation for which the carrier frequency is dependent on the size of the coherent domain and the bio-information is carried as velocity modulation with a
constant wavelength equal to the coherence length and velocity proportional to frequency (Smith C., 1991).

These theories, do show that specific molecular structures may be formed in water upon the influence of serial dilution and succussion of a substance or water "treated" with magnetic fields. The capability of these structures which is implied by these models on "treated" water, would explain the possible "memory" mechanism.

1.7 THE PREPARATION OF HOMOEOPATHIC AND MAGNETIC POTENCIES

In this section, the procedures to potentize water with the imprint of various substances, that is the preparation of homoeopathic remedies, is outlined. Additionally, the procedure to potentize frequencies with magnetic fields and magnetic vector potentials is described.

Traditional homoeopathic remedies are made from plants, animal extracts, minerals, microorganisms, electric and magnetic fields.

The methods formulated by Hahnemann the founder of homoeopathy for the preparation of the mother tincture are:

- Mixture of the juice of the plants with alcohol;
- Maceration of fresh plant;
- Maceration of dried plants;

If the remedy is insoluble in water as in the case of a metal then the method of trituration is used (Vithoulkas, 1980). This is the
solid grinding of lactose sugar with granules of the substance to be potentized. At later stage of grinding and dilution with lactose the mixed granules are dissolved in water or alcohol, or water / alcohol mixtures.

For the present work, the mother tinctures of thirty substances were kindly provided by the Homoeopathic Institute of Brazil.

In the present work the mother tinctures were serially diluted by a factor of ten. That is in 4.5ml of double distilled water 0.5ml of mother tincture is added followed by ten strong succussions on a bench. The new potency is noted 1X and from this 0.5ml is taken with a pipet and added to 4.5 ml of double distilled water. After ten strong succussions the new potency is noted as 2X, and the processes can be repeated untill the desired degree of potentization is achieved.

Tsouris (1991) has given an extensive review of the preparation of homoeopathic potencies with special reference to the guides given by different homoeopathic pharmacopoeias, and alternative methods of preparing homoeopathic remedies.

According to Vithoulkas (1980) any substance in mother tincture form can be potentized with that method irrespective of its molecular complexity.

Critical comments on these hypothetical models of potentized water, are contained in the discussion on page 97a-e.
Water has also been found to potentize with a magnetic vector potential. The magnetic flux density \( B \) is of mathematical necessity related to a vector \( A \) such that \( B = \text{curl} A \). Smith C. (1994a) shows that the process of potentization with the alternating magnetic vector potential separated from the magnetic field are two separate and independent critical conditions:

a) An alternating magnetic vector potential of
\[ A \geq 180 \text{ nWb m}^{-1} \]
is required with a static magnetic field \( \geq 1 \text{mT} \).
Alternatively, an alternating magnetic field of 15 µT at a frequency less than that of the alternating magnetic vector potential or frequency of potentization.

b) To potentize water with the magnetic vector potential only, succession was found to be necessary. A single impact of a glass tube on a wooden bench can provide potentization in an alternating magnetic vector potential \( \geq 20 \text{ pWb m}^{-1} \).

There seemed to be no limit to the frequency range that could be imprinted, magnetic potencies have shown clinical effects from 1mHz to 4200 MHz, and water has been potentized by Smith C. and Best (1989) to 12.5 GHz and in the ultra violet. In general, water ought to be able to store the intermediate frequencies in the sub-millimeter or THz frequency range which Fröhlich considers appropriate for biological coherence (Fröhlich, 1983).
The factors which can inactivate potentized or imprinted water can be classified into two categories. First, the factors which can destroy the physical properties of potentized water and consequently its clinical effects; and secondly, those which can destroy the clinical effects once the remedy is applied to a living system.

The application of heat to raise potentized water above 70 °C will remove any imprinted properties and bio-information. Homoeopathic potencies are used all over the world, thus normal atmospheric temperatures which may be up to 40 °C will not inactivate the effectiveness of a potency. It has been suggested that potentized water passed through a tube 100 Å in diameter, has its imprinted or stored information erased (Smith C. 1990).

One of the major external factors which can inactivate the clinical effects of the remedy is odorous substances such as those of mint, eucalyptus, camphor etc (Vithoulkas 1980). Long term exposure of the potency to strong sun light or monochromatic or polychromatic light will also lead to its neutralization.

The clinical effects of a potency applied to a biological system can be neutralized, by odorous substances, or other homoeopathic remedies called tautopathic remedies which are able to act as an antidote to a given remedy. In the case of magnetic potencies, this takes place at a frequency or set of frequencies different from the ones which initiated the symptoms and which are specific to the particular person.
CHAPTER II

PROPERTIES OF WATER

2.1 INTRODUCTION

This chapter introduces the physical properties of water in terms of its molecular structure and considers whether they can provide a basis for "memory" phenomena in water and other polar liquids.

The most acceptable models proposed for the structure of water are outlined, including the recent quantum field theory approach for the structure of water. In addition the crystalline phase and the possible structural reformation of water at the interface with metals, and the vicinal water in biological cells are reviewed.

2.2 PROPERTIES OF WATER

Throughout natural science, no other substance approaches the complexity and at the same time the simplicity of water. Water is the only chemical compound that occurs naturally in all the three physical states, solid, liquid, and vapour, and the only inorganic liquid that occurs naturally on earth (Franks, 1983). As a chemical substance, water is a good heat conductor; its specific heat is higher than that of any other liquid other than ammonia, and its latent heat of vaporization is twice as high that of any other known liquid. The surface tension of water is the highest of any known liquid, and this is widely used by plants to transfer their nutrients from the soil (Conn and Stumpt, 1966).
In contrast with other substances of similar molecular weight, water has high melting and boiling points. Another important property of water is the anomalous behavior of its density, which has its maximum at 4 °C. In Nature's cold climates, this causes freezing to occur on the surface of the lakes and ponds and allows marine life to carry on as normal below the ice. In fact, water provides life to all biological systems which in turn show a great sensitivity not only to their water content but also to the chemicals dissolved in it. For example D2O or heavy water is chemically identical and physically very similar to water but its effects on biological systems are different in many ways (Thomson, 1963), despite the fact that D2O is present at 150ppm in ordinary water.

The electron density of a single water molecule in the ground state is shown in Figure 2.1 (from Kern and Karplus, 1972). The O-H bond is 0.0958 nm and the O-H-O bond angle is 104.27° (Rao, 1972). Two adjacent water molecules may interact to form a hydrogen bond. A number of possible combinations of two water molecules are shown in Figure 2.2 (from Rao, 1972). The most stable structure is the linear one, and the next more stable is the cyclic, followed by the bifurcated one (Kern and Karplus, 1972). More than two water molecules e.g. three, four or five may also combine and form stable structures as shown in Figure 2.3 (from Rao, 1972), and the flexibility of the H-bond has been calculated to be up to 20°. The ability of the water molecule to form hydrogen bonds make the molecular structure very complex to formulate and this might account for the anomalies in the physical properties of the liquid.

Water molecules may combine differently in the presence of dissolved substances. In the case of non-polar substances,
Figure 2.1. A three dimensional plot of the total electron density of the ground state of water. Redrawn from Kern (1972).
Figure 2.2. Possible configuration of two water molecules. Redrawn from Rao W. (1972).

Figure 2.3. Possible configuration of three water molecules (1), (2), (3), four (4), five (5) water molecules. Redrawn from Rao W. (1972).
water forms hydrophobic clusters as shown in Figure 2.4 (from Franks, 1983), the size of which are dependent on the dissolved substance (Franks, 1972). In general they can vary from pentahedral (five-sides) to tetracathedral (forty-sides) according to the solute (Seffey and McMullan, 1967). The symmetry of the hydrophobic structure is determined by the position of the oxygen atoms but the position of the hydrogen atoms is not known (Seffey and McMullan, 1967). Also it is not known how far the clusters are situated between each other and what is the structure and state of the water between the clusters.

Hydrophilic structures can be formed in water in the presence of polar substances. These are long chains formed by water molecules and the solute, the size and shape of which are once more dependent on the dissolved substance (Sceats and Stuart, 1980). Protonic defects similar to those found in ice may also be involved in both hydrophilic and hydrophobic substances (Pethig, 1986).

All the models proposed for the molecular structure of water are modelled so as to satisfy some of the properties and anomalies found in the liquid and assume 100% purity. But, according to Strillinger (1975) there is no model which can formulate and explain all the physical properties of the liquid. Models for water structure fall into two categories, namely the "uniform model" which assumes that all water molecules have the same structure, and the "mixture models" which assume the presence of two or more species of water (Pethig, 1979).

Early theories for the structure of water considered that the liquid consists of polymers of a few molecules long (Chadwell, 1927), but these theories vanished with the introduction of the concept of hydrogen bonding. Franks (1983) investigated the
Figure 2.4. A typical clathrate hydrate cage geometry. Circles represent oxygen atoms and the lines hydrogen bonds. Redrawn from Franks F. (1972).
H-bonds and they proposed a model for the liquid consisting of clusters of H-bonds breaking and bonding, many at a time. Overall, they have independent timing for breaking and forming bonds, but each cluster performs cooperatively with respect to the H-bonds involved. The formation and dissociation of these flickering clusters is governed by local energy fluctuations (Nemethy and Scherga, 1961a) and impose large local energy fluctuations. The thermodynamic equilibrium is met if surrounding water molecules are in the monomer state. The size of the clusters is calculated to be of the order of forty H-bonds and bonded together as the ice-H structure (Nemethy and Scherga, 1961b). This model satisfies the density variations in water and the structural reformation for the hydrophobic and hydrophylic structures. Computer simulation programs have shown that large energy fluctuations in water result from the cooperative H-bond bonding in the liquid (Tanaka and Ohmine, 1987); (Ohmine and Tanaka, 1988). The energy is classified under in two headings: a) the fast component associated with librational motions, and b) the slow component associated with water binding structure (Ohmine and Tanaka, 1988).

Another widely accepted model for the structure of water considers the liquid as having a structure similar to a gel (Gibbs et al., 1973). The liquid is viewed as a randomly branched gel with randomly branched hydrogen bonds forming large rings. This model satisfactorily accounts for the melting and boiling points of the liquid.

Another important model visualizes water as having solid-like clusters in equilibrium with each other and separated by water in the gas phase. The structured water is not free to rotate but the single water molecules are free to rotate (Eyring, 1963). This model satisfies the dielectric relaxation constants of water.
In order to investigate the molecular structure of a liquid, the examination of the crystalline structure of its solid often reveals significant information. In the case of water, the complexity of the ice is determined by the liquid from which it freezes but this introduces as many unsolved problems as there are in the liquid phase (Franks, 1983). Ice structure is sensitive to pressure and several types of ice at various pressure, and temperature conditions having different structures have been found (Bridgman, 1949). At normal atmospheric pressure, the ice structure is in the form of hexagons as shown in Figure 2.5 (from Franks, 1983). It should be noted that the oxygen atoms are perfectly ordered but this is not the case for the hydrogen atoms. In the crystalline structure of ice, two types of defects are found. The first defect is due to the positive and negative ions H3O+ and OH− produced in pairs by the shifting of protons along the O-O bonds as shown in Figure 2.6 (Jaccard, 1965). This defect can be influenced by thermal activation and can explain the A.C conductivity of ice. The second defect is due to the fact that certain bonds are occupied by protons or have no protons at all, thus leaving an empty bond in the lattice. Proton jumping can then take place to the oxygen atoms and eventually protons move through the lattice. This defect accounts for the D.C conductivity of ice (Franks, 1983).
Figure 2.5. Crystal structure of hexagonal ice (ice-h). Filled in circles represent oxygen atoms and the open hydrogen atoms. Redrawn from Franks F. (1983).
Figure 2.6. a) Ionic, b) non ionic lattice defect in ice. Redrawn from Jaccard C. (1965).
2.3 QUANTUM FIELD THEORY APPROACH TO WATER

The strange properties of water discussed above, have not been fully explained by any of the theories proposed. Recent theoretical studies have applied Quantum Field Theory (QFT) to the problem and have shown that a macroscopic permanent polarization can easily arise in water in conditions of electric disturbance. Such conditions can arise from the local field produced by a macromolecule, or a colloidal grain. Preparata (1989) and Del Giudice and Preparata, (1989) showed that coherent exchange of radiation between the water electric dipoles and the existing electric field, satisfies conditions for generating ordered structures. Such coherent structures are microscopic, a domain may be only a few hundred microns in size. The outcome is that water can behave as a free electric dipole laser (Del Giudice et al., 1988). Under these conditions the correct static dielectric constant can be derived as well as the correct latent heat of vaporization (Del Guidice and Preparata, 1989).

2.4 VICINAL AND INTERFACIAL WATER

The concept of vicinal water was originally introduced to explain a large number of anomalous thermal responses observed at aqueous surfaces and in colloidal systems. Vicinal water can be found adjacent to most insoluble particles in water, biological systems and micromolecules up to distances of about 10 nm or 30 to 150 water molecules.

The existence of vicinal water is important to this work since it represents water at an interfacial level which may
provide essential coupling between coherent water and an electrode transducer as used in an instrument, and within biological systems.

Vicinal water is distinguished from bulk water through the anomalies it imposes on its physical properties. Drost-Hansen (1977) recorded anomalies in the dielectric constant of polystyrene spheres in water as a function of temperature. Etzer and Drost-Hansen (1987) investigating the viscosity and conductivity of water between mica plates in distance of 5 nm and found them to differ from those of ordinary water as a function of temperature.

The disjoining pressure measurements by Derjaguin and Churaev, (1974) showed anomalies with temperature, and a theoretical treatment of vicinal water concluded that these anomalies are mainly a result of structural reconstruction of water in the vicinity of a surface. Drost-Hansen (1977) has reported on ion selectivity phenomena in vicinal water from a study of the distribution of sodium and potassium between the bulk phase and vicinal water in the pores of silica gel. Etzer and Drost-Hansen, (1987) studied the surface tension which showed anomalies with temperature over distances of 3 to 5 nm.

Bedglehole (1987) measured the coefficient of optical ellipticity, which is related to the interface structure of a liquid through local variations in the refractive index in the interface region indicating change in the surface tension of distances up to 5 nm.

The study of coalescence gives information about the intermolecular bonds in water. Results from this study of a water/water interface showed free bonds pointing outwards from the surface of the liquid (Owe Berg, 1965).
In thin films of water, computer simulation programs showed larger densities for water and interpreted this as hydrogen bond breakage, with the hydrogen bonds pointing outwards and density fluctuations in the liquid (Zhu et al., 1991).

Measurements of the dielectric constant of water in the microwave region have shown a considerable degree of ordered structuring existing in water adjacent to colloids (Drost-Hansen, 1980).

Computer simulation programs for the structure of water interfaces conclude that water molecules in the vapour phase are associated with large surface electric potentials (Croxton, 1981).

The theoretical treatment of these phenomena predicts an ordered structure taken up by water near the ice and extending out to 30\(\mu\)m. Other studies investigating ultrasound velocity in vicinal water have found anomalies with respect to temperature as a result of density variations with distance in the liquid (Etzler and Drost-Hansen, 1987).

Despite the amount of data on vicinal water, there is no particular model for a vicinal water structure but, the most widely accepted structure for the vicinal water is a hydrophobic one (Etzler and Drost-Hansen, 1987).

Thus, the only conclusion that can be drawn regarding the structure of vicinal water is that something exists, but with no specific details as to how far any hydrophobic clusters may be arranged, nor how large or complex they might be.

In biological cell water, there are three distinct states. a) "Bound water" which is just a few molecular layers thick and is inside the cell wall, b) "vicinal water" existing between 3 to 50 nm from the cell wall and c) "bulk water" which has the usual
properties of water at distances greater than 50 nm (Clegg, 1987). The latter is not affected by the presence of biomolecules, but bound water is supposed to be responsible for creating the environment in which metabolic enzymatic reactions can take place. Bound water also refers to water which is fixed by H-Bonds to specific sites on biomolecules or to the specific hydration water of the biomolecule (Clegg, 1983).

Another way to look at the problem of interfacial water is through metals or conducting plates in contact with water. In general, results from computer simulation programs have predicted anomalies in both the dynamic and bulk properties of the liquid in the presence of conducting plates, and electric fields applied through the plates (Zhu and Robinson, 1990); (Greiger, 1982). These studies calculate the non-linear dielectric behaviour of water (Howard and Levy, 1990). Distinct phase transitions are associated even with zero applied field and spontaneous symmetry breaking is expected. In the case of an applied field between conducting plates, long range ordering parallel to the field vector is expected to set in (Watanabe and Brodsky, 1991). This long range ordering is expected to extend to distances of order of 100 nm.

It has been proposed by Benderskii and Brodskii, (1987) that phase transitions in thin film monolayers of water take place as a result of an antiferroelectric type of ordering in water monolayers. Increasing the potential between the plates, resulting in a para-electric state (Brodskii, 1989). The reconstruction of a surface structure is defined as a situation whereby the surface atoms of a semi-infinite metal structure do not take up the sites which correspond to its ideal bulk crystal lattice (Brodskii, 1989). Reports have suggested that gold can reconstruct its
structure in the presence of aqueous electrolyte solutions so as to take up a (5x20) super-structure of hexagonal close packed layers on the top of its original structure (Kolb and Schneider 1980). This reconstructed gold structure is found to be more stable than gold in its ordinary structural state and, that gold can sustain this state in certain electrolyte solutions and electropotentials depend on the concentrations and type of electrolyte. However, the same (5x20) structure for Au has been experimentally proved to take place when flame treatment is applied to gold (Kolb, 1985); (D'Agostino and Poss, 1987).

This process involves flaming the electrodes at 800 C° for about 2-3 seconds. This is a very important effect in respect of the present work since the Au electrodes used were always flamed at approximately this temperature and for this time before use, this was initially in order to sterilize and decompose any organic matter on the surface.

2.5 ACOUSTIC PROPERTIES OF WATER

By definition, when a system in equilibrium is perturbated into a non-equilibrium state, the restored equilibrium is defined as the relaxation process.

The liquid water at its molecular level is not in thermodynamical equilibrium since it has the ability to flow.

The time taken for the system to return to its equilibrium state from its original form is called structural relaxation time. When a low-amplitude, longitudinal sound wave is applied to water, it results in alternate regions of compression and expansions. Thus any given region of the liquid is vibrating, creating higher and lower densities in the liquid within this
region. So the applied pressure fluctuations in one part of a system may lead to both density and temperature fluctuations. If the period of the applied sound wave exceeds the periods (shorter periods) of the structural relaxation time no flow can occur, and the viscosity of the liquid goes to zero. If a step function of pressure is applied to a liquid, the change in volume could be separated into two points. First a rapid, solid-like change followed by a slower relaxational change. In the case of water the structural relaxation time is in the order of $10^{-12}$ seconds (Davis and Jarzynski, 1972). Any acoustic exitation therefore at the low frequency range and at normal atmospheric pressure should not alter significantly any of the thermodynamic properties of water nor expected to have.
CHAPTER III

ELECTRIC AND MAGNETIC SHIELDING

3.1 INTRODUCTION

A high performance electric and magnetic shielding enclosure was designed and built in order to reduce environmental interference to a level below the sensitivity of the low noise amplifier necessary for the detection of resonances in water. A high performance shielding enclosure had previously been recommended by a previous worker (Ludwig, 1988). An environment free from any electric and magnetic fields, was considered necessary to give the reassurance that no additional bio-information could be imprinted into water samples during the experiments.

In this Chapter, the theory involved in low frequency electric and magnetic field shielding is outlined and measured values for the performance of the shielding enclosures constructed are given. Finally, a test has been developed and applied to these shielding enclosures which is able to provide an accurate value for their shielding effectiveness.

3.2 SHIELDING THEORY

A "shield" is defined in the IEEE Standards on Industrial Electronics as "Material used to suppress the effect of an electric or magnetic field within or beyond a defined region." A
"shielding enclosure" is defined as, "A structure composed of such material" (Ott, 1979).

Several methods are available for the mathematical analysis and prediction of the shielding effectiveness of such an enclosure (Ott, 1979). The classical approach is by solving Maxwell's field equations with the appropriate boundary conditions. However, exact solutions are available only for certain idealized geometries such as infinite planes, infinitely long cylinders, and a sphere. For more complex structures, the exact solutions are so complex that they are of little use to an engineer (Bridges, 1968).

In the literature, there are two main techniques available to estimate shielding performance. These are: 1) the transmission line model and, 2) the circuit theory approach as developed by King (1933). The first model is based on the assumption that a plane wave strikes a sheet of metal of infinite extent. This makes the technique suitable for the case where the geometry of the enclosure is large compared to a wavelength at the frequency of investigation, and the distance between the shield and the source is relatively large.

The second approach considers the entire geometry of the enclosure as a whole. This is suitable for the ELF frequency range (Miller and Bridges, 1968) and therefore is suitable for the present purpose. However, neither the circuit theory approach nor any other approach involving calculations can give a precise value for the shielding effectiveness, since neither the materials nor the construction of the enclosure are "ideal". Those factors which are excluded from the calculations are outlined in section 3.6.1.
3.3 CIRCUIT THEORY APPROACH TO SHIELDING EFFECTIVENESS

First, the effects of low frequency electric fields are considered and compared to those of low frequency magnetic fields striking a rectangular enclosure such as that to be used.

In the case where a static electric field is applied to the enclosure, a charge is induced on the surface of the box and this generates the electric flux as shown in Figure 3.1 (a) (Miller, 1966). Each flux line of the field terminates on an induced charge. Since there are no net charges within the box, no field penetrates the enclosure.

In the case of an alternating applied field, energy is coupled into the enclosure as the field changes. The charges induced redistribute themselves and effectively cause a current to flow between the upper and lower edges of the box. This current flow represents a resistive current loop between the upper and lower portions of the box and therefore, both electric and magnetic field components will appear inside the enclosure. The charge induced is proportional to the magnitude of the applied field and thus the current is proportional to the rate of change of the applied electric field.

At low frequencies, the current induced will be small but it increases directly with increase in frequency. Any sharp corners of the enclosure concentrate the charge there.

The calculations of shielding effectiveness for a rectangular enclosure in the presence of an electric field are very complicated. A simpler approach was used. This involves approximating the rectangular box to a hollow sphere of the same volume.
Figure 3.1. (a) Quasi-static electric field distribution and induced currents Redrawn from (Miller 1966).

Figure 3.1. (b) Induced currents on the structure from the time-varying magnetic fields. Redrawn from (Miller 1966).
Then, the induced surface charge density is given by

\[ q(\theta) = 3\varepsilon_0 E_0 \cos(\theta) \]  \hspace{1cm} (3.1)

where \( \varepsilon_0 = 8.8542 \times 10^{-12} \) F m\(^{-1}\) the permittivity of free space, and \( E_0 \) is the zero frequency applied electric field. Integrating over the hemisphere gives

\[ q = 3\pi \varepsilon_0 a^2 E_0 \]  \hspace{1cm} (3.2)

where, \( a \) is the radius of the sphere (the value chosen for this calculation was that of a sphere having the same volume as the rectangular enclosure used).

In the case of a time-varying field,

\[ q(t) = 3\pi \varepsilon_0 E_0 a^2 e^{j\omega t} \]  \hspace{1cm} (3.3)

gives the resulting net charge flowing across the equator, and the current as

\[ \frac{dq}{dt}(t) = j\omega 3\pi \varepsilon_0 E_0 a^2 e^{j\omega t} \]  \hspace{1cm} (3.4)

For low frequencies, the voltage drop across an equatorial ring of thickness \( d \) and height \( h \) is equal to the \((I \times R)\) voltage drop across this loop.
The resistance of the loop $R_h$ is equal to

$$R_h = \frac{h}{\sigma_a 2\pi ad} \quad (3.5)$$

where $\sigma_a$ is the conductivity of the sphere wall material.

The voltage drop across it is then

$$V_h(t) = \frac{j\omega \varepsilon_0 a^2 E_0 e^{j\omega t}}{2 \sigma_a d} h \quad (3.6)$$

Because of symmetry, the equipotential lines near the equator are parallel to the equatorial plane making the electric field intensity at the centre of the sphere the same as that on a surface very close to the equator (this is not exactly the case for rectangular structures). Therefore, the electric field intensity at the centre is equal to the equatorial loop ($I \times R$) voltage drop divided by the loop height $h$ where

$$E_i = \frac{V_h}{h} = j \frac{3\omega \varepsilon_0 a E_0}{2\sigma_a d} \quad (3.7)$$

"Skin depth" is defined as the distance required for a wave propagating in a material to attenuate by 1/e or (37%) of its original value (Morrison, 1981) and is given by
The ratio of the high-frequency to low-frequency surface loop impedance is given by

\[ \frac{Z_{HF}}{Z_{LF}} = \sqrt{\frac{2d}{\delta}} \]  

(3.9)

provided that \( d \gg \delta \) and \( a \gg d \). Thus, the applied voltage is attenuated before it appears inside the enclosure by an approximate factor of

\[ 2e^{-d/\delta} \]  

(3.10)

For a high frequency applied field, where \( d \gg \delta \), \( 2\pi/\lambda \ll 1 \) and \( a \gg d \) the internal field at the centre is

\[ E_i = \frac{j3\sqrt{2}}{\sigma_a} \frac{\omega \epsilon \epsilon_0 a}{\delta} e^{-d/\delta} \]  

(3.11)

By definition, the "shielding effectiveness" (SE) is determined by the ratio of the externally applied field to the field appearing inside the enclosure and is given by
In the case of a homogeneous magnetic field striking the enclosure, eddy currents will be produced and flow as shown in Figure 3.1(b) (from Miller, 1966). These currents occur because adjacent eddy current elements cancel and leave a concentrated current flow near the edges.

For the purpose of calculating the shielding effectiveness, the enclosure is modelled as single (shorted-turn) loop coil having inductance L and resistance R. The time varying magnetic field induces a voltage in the enclosure considered as a small loop which is proportional to the frequency of the applied field as modelled in Figure 3.2 (a) (from Miller, 1966). At very low frequencies the loop current is proportional to the applied voltage divided by the resistance of the loop. This current and the field associated with it are 90° out-of-phase with the applied magnetic field, and little cancellation or reflection is expected. As the frequency of the applied field increases, the inductive

\[
SE = 20 \log_{10} \left| \frac{E_0}{E_1} \right| \quad (3.12)
\]

\[
SE = 20 \log_{10} \frac{3 \sqrt{2} \omega \epsilon_0 \mu_0 a e^{-d/\delta}}{\sigma \delta} \quad (3.13)
\]
Figure 3.2.a). Large to small flat loops
Redrawn from (Miller 1966).

Figure 3.2.b). Equivalent circuit of the
closure (King 1933).
reactance of the single turn tends to dominate and the current flow in that turn tends to dominate so the current flow eventually comes in-phase with the field. As the frequency is further increased, a significant amount of energy may be absorbed in the walls by the skin-effect mechanism. This causes the fields which appear on the outside of the enclosure to be attenuated exponentially before appearing on the interior surface. In addition, the skin-effect causes the series impedance to increase which in turn tends to reduce the rate of increase of the shielding effectiveness with increase in frequency.

Thus, the shielding effectiveness of the enclosure can be estimated as follows. Assuming no localization of the field and uniform current distribution, the enclosure can be modelled as shown in Figure 3.2(b) (King, 1933). For a rectangular shielding enclosure with dimensions $a, b, d$ and the large loop generating the field $\alpha, \beta, D$, the inductance of the large loop regarded as a transverse wave guide is given by

\[
L_1 = \frac{\alpha}{\beta} D
\]  

(3.14)

and for the rectangular enclosure is given by

\[
L_s = \mu \frac{a}{b} d
\]  

(3.15)

The magnetic field produced by the parallel loop-cum waveguide is transverse and can be written as
where $I_1$ is the current of the coil $\mu$ the permeability of the medium.

The mutual inductance $M$ is given by

$$e_s = M_{1-s} \frac{dI_1}{dt}$$

(3.17)

The voltage appearing around the loops is

$$e_s = \frac{ad\mu}{\beta} \frac{dI_1}{dt}$$

(3.18)

Thus, the mutual inductance

$$M_{1-s} = \frac{ad\mu}{\beta}$$

(3.19)

as represented in the equivalent circuit in Figure 3.2(b) (from King, 1933), where $R_s$ is the resistance of the small loop and $L_s$ is the leakage inductance. The latter is very small in the case of a low frequency applied field and solid wall enclosures like the one used, and can be ignored. At low frequencies then,
where the first term is the voltage drop around the small loop. The current $I_1$ in the small loop is given by

$$I_1 = \frac{j\omega M_{1-s} I_1}{R_s + j\omega L_s}$$

(3.21)

and $I_2$

$$I_2 = \frac{\frac{j\omega}{\beta} \left( \frac{\alpha d u}{\beta} \right) I_1}{R_s + j\omega L_s}$$

(3.22)

and the magnetic field within the loop is

$$B_1 - B_2 = \frac{\mu I_1}{\beta} - \frac{\mu}{b} \left[ \frac{j\omega M_{1-s} I_1}{R_s + j\omega L_s} \right]$$

(3.23)

therefore, the shielding effectiveness

$$SE = 20 \log_{10} \left( \frac{B_1}{B_1 - B_2} \right)$$

(3.24)
and the overall shielding effectiveness including the skin depth effect is given by

\[ SE = 20 \log_{10}\left[ \left( \frac{\omega L_s}{R_s} \frac{2d}{\delta} \frac{1}{2e^{-d/\delta}} \right) \right] \]  

(3.25)

For the overall shielding effectiveness of these two rectangular boxes one inside the other, there is not even an approximate circuit theory available. The closest approximation that can be made is to use the infinite cylinder theory approach after Shenfield (1968). Lengthy calculations result in the overall shielding effectiveness of multiple infinite long cylindrical enclosures one positioned coaxially inside the other. In the case of two such enclosures,

\[ S = 1 + S_1 + S_2 + S_1 S_2 \left( 1 - \frac{V_1}{V_2} \right) \]  

(3.26)

where \( V_1 \) and \( V_2 \) are the volumes of the first and second enclosure respectively. According to this equation, the over-all shielding effectiveness of the arrangement at various frequencies has been calculated and is plotted in Figure 3.3.
This section outlines the test procedure used for the determination of the shielding effectiveness of the various shielding enclosures used. The methods available for testing the shielding effectiveness in the kHz frequency range have been summarized by O'Young (1968). The most suitable method for measuring the shielding effectiveness is "The Large Transmitting Loop to Small Detecting Loop Method". In this, a significant portion of the enclosure is subjected to a testing current by surrounding the enclosure with a large transmitting loop or coil so that a gross measure of the effectiveness of the box can be obtained (Bridges 1968). The large loop shown in Figure 3.4 causes uniform currents to flow across all seams of the shielding enclosure in a uniform manner so that one measurement is significant and gives an indication of the shielding effectiveness at the given applied frequency. This makes the time taken for a measurement small and the set-up relatively easy. The method was originally developed by (Bridges, 1968) to test screening rooms rather than relatively small enclosures such as the one used. It had to be modified in order to suit the dimensions of the present system and the particular measurements to be made. The arrangement is shown in Figure 3.5, in which the large loop consisted of 105 turns of enamelled copper wire, 0.5 mm in diameter, wound on the posts of a plastic frame constructed for this experiment. The loop is kept 5 cm away from the enclosure as recommended by Vance (1989).

In order to produce an even field in all planes which effectively tests all sides of the enclosure, the large loop was positioned so that \( c = \frac{w}{l + w} h = 14 \text{cm}, \quad d = \frac{1}{l + w} h = 20 \text{cm}, \) as
Figure 3.4. Coordinate system for current loop generating magnetic field $B_z$ (Wever 1956).
Figure 3.5 Set up for testing shielding effectiveness of the enclosures.
recommended by Bridges (1968). The large coil had dimensions 57 x 72 cm and its measured self-resonance frequency was at 6.3 kHz. The magnetic field produced by the coil was 18.9 μT (0.189 G) at the origin \( B_{(0,0,0)} \), as shown in Figure 3.4 (Weber, 1965) when driven by a 100 mA current.

The coil was driven from a constant-voltage amplifier originally made to deliver a constant power over the audio frequency range to inductive loads. The circuit diagram is shown in Figure 3.6. (Technics, 1985).

This circuit was modified in order to be able to supply a high impedance load as well as low impedance loads. It also offers low distortion and a flat frequency response from 500mHz to 200kHz and this was confirmed by measurements.

The load resistance versus output current characteristic of the amplifier is shown in Figure 3.7. Referring to Graph 3.7, the \( R/I \) characteristic becomes linear at loads in the order 100 and remains linear at higher resistances. There was one limitation, this was that input voltages of 2 V(p.p) and higher were limited by the smallest resistance values that could be driven.

In order to supply the transmitting loop with a constant current from a constant voltage amplifier it had to have a gain of 2 and drive a variable auto-transformer (type-Variac 8A) as shown in Figure 3.5. This arrangement offers an adjustable current feeding the coil with up to 250 mA RMS available over the frequency range from near dc to 6 kHz at which frequency self-resonance sets in. For this particular experiment, the current was actually kept constant at 100 mA at which value minimum coupling of the testing field to the testing apparatus was observed. The test frequencies actually used were 10Hz 100Hz, 1kHz, and 2 kHz.
Figure 3.6. Circuit diagram of the constant voltage amplifier.
Figure 3.7 Load resistance versus output current for the constant voltage amplifier.
The transducer used for the detection of the AC magnetic field was a coil of 3848 turns, wound from copper wire 0.125 mm in diameter on a plastic cylinder 1.5 cm in diameter and 5 cm in length. The calculated sensitivity of the coil was $\approx 3\text{mV/}\mu\text{T (300mV/G)}$ at 50 Hz, and the resonance frequency was measured at 6.3 kHz. The upper frequency limit was thus the same for both coils.

For the DC magnetic field test of the enclosure two Hall Effect transducers (type UGN3501U) were used. These were placed back-to-back in order to double the sensitivity of the system as shown in Figure 3.8. This provided a sensitivity of $\approx 5\text{mV/}\mu\text{T (0.5 V/G)}$ for DC magnetic fields according to the Allegro Microsystems INC data sheet (1989).

Referring to the circuit diagram in Figure 3.8, the RC network at the output has a cut-off frequency of 1.5 Hz, thus ensuring that only the values for the static field are measured. The Hall Effect device specifications guarantee a linear output voltage versus applied magnetic field and a noise output voltage $\approx 10\mu\text{V}$ Allegro Microsystems INC (1989).

The pick-up coil was placed in the middle of the loop in all planes and values for the voltages induced within the loop were recorded. Then, the enclosure was placed inside the loop the coil was positioned inside, again in the middle of the loop in all planes, and another set of measurements was obtained. The ratio of the two measured voltages was converted to a voltage ratio as shown in Figure 3.3.

The same procedure was carried out for the second enclosure and its shielding effectiveness is also shown in Figure 3.3.

The last experiment was carried out with one enclosure inside
Figure 3.8. Circuit diagram of the static magnetometer.
the other so the performance of both enclosures together could be evaluated and this also is shown in Figure 3.3.

A final check involved using the coaxial wire shorted with a 500 Ω resistor (the equivalent resistance of the coil) placed in the middle of the loop in order to verify that there was no pick-up voltage on the coaxial wire connecting the coil to the voltage measuring circuit.

Finally, the DC performance of the enclosures was tested with the Hall Effect sensors. These sensors were placed in the middle of the enclosures and the outer coil was fed with 2A DC. The limiting sensitivity of the voltmeter was 1mV and this showed no detectable voltage from the sensors. Thus, the static field shielding effectiveness exceeded the limit of detection which was 61 dB.

3.5 RESULTS

Using the equations (3.13), the electric field shielding effectiveness of steel enclosure was calculated on the assumption of an effective radius \( a = 0.274 \) m for the sphere having the same volume and \( \sigma_a = 10^8 \) Ω\(^{-1}\)m\(^{-1}\), and \( \mu_a = 1.2 \times 10^{-3} \) H m\(^{-1}\) as typical values for mild steel (Hemming, 1991).

The electric field shielding effectiveness comes to \( \approx 280 \) dB at 100Hz which is consistent with published values by Hemming (1991).

Following the equation (3.15) the shielding effectiveness of the individual enclosures was calculated.

The first enclosure to be considered has dimensions \( l = 0.5 \) m,
h = 0.35m, w = 0.35 m, and \( \sigma_\alpha = 10^8 \, \Omega^{-1} m^{-1} \) and \( \mu_\alpha = 1.2^{-3} \, H \, m^{-1} \) as typical values for mild steel (Hemming, 1991). Its calculated shielding effectiveness is 34.8 dB at 100 Hz.

For a mu-metal box with dimensions \( l = 0.2m, h = 0.13m, w = 0.13m \), and \( \sigma_a = 32^{10} \, \Omega^{-1} m^{-1} \), and \( \mu = 0.125 \, H \, m^{-1} \) as typical values for mu-metal (Hemming, 1991) its calculated shielding effectiveness is 38.1 dB at 100Hz.

The over-all shielding effectiveness of the boxes one placed inside the other was calculated according to the equation (3.26) and the SE for the frequency range from 10Hz to 2kHz is shown in Figure 3.3.

The calculated and measured values of the individual shielding enclosures, and the overall shielding effectiveness of both enclosures is plotted in Figure 3.3.

The measurement of the DC magnetic shielding effectiveness outlined in section 3.4, showed that the overall shielding effectiveness of both boxes was better than 61 dB.

The results for the magnetic shielding effectiveness of the individual enclosures are in good agreement with published and calculated data for similar structures (Schulz, 1968); (Vance, 1989).

### 3.6 COMMENTS

The comments are divided into two subsections (3.6.1) and (3.6.2). Section (3.6.1) includes comments on the calculations followed to estimate the shielding effectiveness, and the factors which could alter the shielding performance of the enclosure and could not be included in the calculations. Section (3.6.2) includes comments on the techniques employed for measuring the
shielding effectiveness of the enclosures.

3.6.1 COMMENTS ON THE CALCULATION OF SHIELDING EFFECTIVENESS

The following paragraphs discuss those factors which affect the overall shielding effectiveness and which are not included in the calculations already outlined in section 3.3.

a) Variable permittivity: The variation of permittivity within the material will affect the overall performance of the shield and the performance at the particular location of any anomaly in permittivity when subjected to high field strengths (Vance, 1988).

b) Remanance Magnetization: In general, any magnetic material in a shield can acquire a remanant magnetization, either locally or overall, through application of magnetic field or mechanical shock. Depending on the magnitude and shape the field giving rise to magnetization, the remanance will either add to or subtract from the field inside the shield, either over small areas or throughout. Care therefore must be taken during the use of the enclosure and with the materials or tools used near it. High permeability materials like mu-metal must not be subjected to mechanical shock of any form including machining operations since these will degrade the magnetic performance (Vance, 1989) and factory re-annealing will be required.

c) Effect of Discontinuities: In the case of large enclosures like the one for the present application it is not possible to have a near-absolute shielding within a reasonable cost budget due to manufacturing costs and practical difficulties. It requires careful balancing of all the factors involved to achieve an
effective design. Electrical discontinuities and changes in the thickness of the material will give corresponding changes in the eddy currents and affect the overall performance. For this reason two enclosures were used and the design of both enclosures was kept as simple as possible so as to require the minimum of welded areas as recommended by Hemming (1991). The holes made in the enclosures for the access of wires were made as far away from the corners as possible in order to avoid disturbance of the concentrated eddy currents in these regions.

d) High permeability materials: These can offer high performance with relative small thickness. However they require high temperature annealing with all drilling and welding completed prior to the annealing in an inert atmosphere, and afterwards careful handling with no subjection of the enclosure to strong mechanical shock, given this, they should retain their desired properties indefinitely (Vance, 1988).

e) Standard Values: Finally, the values taken for the conductivity and permeability of the materials are "standard values" and these may differ from the actual materials used.

3.6.2 COMMENTS ON THE MEASUREMENTS OF SHIELDING EFFECTIVENESS

The following paragraphs discuss those factors which affect the measurement of the shielding enclosures.

The values for the calculated shielding effectiveness was in a good agreement with the measured values at the frequency of 100 Hz. Below and above that frequency, a deviation of up to 40 dB was observed. This was due to large approximations involved for the
estimation of the shielding boxes especially for the case of estimating the SE of both boxes. The measured values are expected to be more precise than the calculated ones. However, with the particular coil arrangement used for measuring the SE, electromagnetic fields could couple capacitively to the small coil transducer thus producing an error in the measurements. In order to eliminate this and other such errors and to have a more accurate reading, the test loop should have been made much larger and experiments should have been carried out in the open air or away from any steel framed building.
CHAPTER IV

LOW NOISE INSTRUMENTATION

4.1 INTRODUCTION

Previous work by Ludwig (1988) had detected resonances in homoeopathic potencies using a low noise amplifier. Accordingly, in the present work the best practicable noise performance was aimed for.

In this Chapter, the design and construction of a low noise amplifier is described. A small section is devoted to the noise generated by electronic components. This is followed by the design description of the amplifier unit actually built.

4.2 LOW NOISE AMPLIFIERS

The reasons for the choice of discrete devices are outlined and their use in a low noise preamplification stage as well as in the subsequent stages of the low noise amplifier used for this work are given. Finally, the amplifier noise performance is measured and given in terms of its spectral density function as measured by a spectrum analyzer.

4.2.1 PHYSICAL PROPERTIES OF NOISE

Noise in the broadest sense, can be defined as any unwanted disturbance that occurs or interferes with a desired signal.
Noise is in other words a random signal. It consists of frequency components which are random in both amplitude and phase. However, it is possible to predict certain features of the randomness of noise. Most types of noise have a Gaussian or Normal distribution of instantaneous amplitudes with time (Bell, 1960).

The noise voltage level is expressed in root-mean-square (r.m.s.) quantities and the peak-to-peak value is expected to be six-times higher than the r.m.s. for 99.7 % of the time (Keithley, 1987).

For a noise voltage \( n(t) \), the r.m.s. is defined as:

\[
\sqrt{\frac{1}{T} \int_0^T n^2(t) \, dt}.
\]  

Where the bar indicates an average value for a relatively long time \( T \).

Random noise can also be characterized in the frequency domain. The most important characteristic here is the spectral density function (SDF) which is defined as the Fourier transform of the temporal autocorrelation function (Bell, 1960). In practice it represents the time average noise power \( n^2(t) \) over a 1 Hz bandwidth as a function of frequency.

The spectral density function SDF of a voltage \( e_n(t) \) is designated as \( e_n^2(f) \) and that of current \( I_n^2(f) \). Since the voltages and currents are squared, this represents normalized power density.

Noise sources are often characterized in terms of a spot value, defined as a square root of power density designated as
V(rms) / √Hz or A(rms) / √Hz. This is a matter of practical convenience, but it limits the intuitive physical meaning. The spot noise is numerically equal to the rms value over a 1Hz bandwidth. The notation used for this is

\[ E_n = \sqrt{\frac{e^2}{2}} (f) \quad \text{and} \quad I_n = \sqrt{\frac{I_n^2}{2}} (f). \]  

Noise in electronic devices is to be attributed to two main processes, Thermal noise and Shot noise.

Thermal or Johnson noise is caused by the randomly excited vibrations of charge carriers in any conductor. It was first observed by Johnson of Bell Telephone Laboratories after whom it is called and it was theoretically analyzed by Nyquist in 1928. Thermal noise is characterized by its flat frequency spectrum and for this reason it is also called "white noise". The power density value of "white noise" is calculated as follows:

\[ e^2 = 4 KT R \quad (V^2/ \text{Hz}) \]  

where \( T \) is the absolute temperature of the resistor, \( K = 1.38 \times 10^{-23} \) is the Boltzmann constant, \( \text{in Joule per Kelvin} \).

In semiconductors and vacuum tubes, there is a component of the noise produced which is due to the nature of the current flowing in the device, this is called Shot noise. The electron charge flow is not smooth and continuous but is rather like a series of pulses of current or clusters of charge within the constant average flow of carriers each one carrying a single electronic charge. The spectral density of this source is given
by:

\[
I_n^2 = 2qI_o \quad (\text{A}^2/\text{Hz}) \quad (4.4)
\]

Where \( q \) is the electronic charge and equals \( 1.60217 \times 10^{-19} \), \( I_o \) is the DC current passing through the device.

Both the Thermal noise and the Shot noise have a constant spectral density (Bell, 1960).

In semiconductor devices, there is an additional noise component which is inversely proportional to frequency, it is the so called \( \frac{1}{f} \) noise, which is also referred to as excess, or flicker, or pink-noise. In semiconductors, it results from fluctuations in the conductivity of the material (Van Der Ziel, 1978). This as a consequence produces a fluctuating voltage drop when a low frequency current flows and constitutes what is usually called flicker noise.

The spectral density is given by:

\[
I_n^2 = I_n^2_0 \times \left( 1 + \frac{f_c}{f^n} \right) \quad (4.5)
\]

where \( I_n^2_0 \) represents the white shot noise component, \( f_c \) is the break-point where flicker noise is equal in magnitude to the white noise component, and \( \frac{1}{f^n} \) is the flicker noise component where \( n \) is a constant varying between 0.6, 1.1 and which depends on the particular device involved (Halford, 1968).
4.2.2 LOW NOISE DESIGN

When designing an amplifier, it is always a prime objective to keep the design simple. In most cases, integrated circuits and operational amplifiers offer simplicity and flexibility to the design in terms of gain and frequency response of an amplifier circuit. A wide choice of devices are readily available in the market for designing with integrated circuits often giving an added flexibility in respect of being able to change the performance of a circuit by changing the operational amplifier to one with better or different electrical characteristics. However, operational amplifiers do tend to become difficult to operate at the limits of their specifications, especially if they are to be driven by inductive or capacitive sources. Therefore, integrated circuits are not always the right solution and one must look at discrete devices as an alternative.

In the present case, the objectives set for the head amplifier were for it to be sensitive to voltage levels in the nV range, which implies that it also had to have a low drift, and to have a frequency response from a few mHz to 20 kHz. In addition, it has to be compatible to a variety of sensors such as coils or electrodes, inductive or capacitive sources, which required it to have a very high input impedance.

The choice for discrete devices had to be made between Bipolar Junction Transistors (BJT), Field Effect Transistors (FET) and Metal Oxide Semiconductor Field Effect Transistors (MOSFET).

Low noise bipolar transistors have low equivalent input voltage noise at mid-frequencies, that is in the kHz region, but suffer from a relative low input impedance. In addition, BJT's have a considerable equivalent input current noise (Van Der Ziel
A, 1970). However, they have an advantage over FET's through a higher transconductance value and are often the best choice for low to moderate values of source impedance.

Both the JFET and the MOSFET devices offer high input impedance and therefore only a very small amount of equivalent input current noise. MOSFET's and some FET's suffer at low frequencies from high flicker noise levels which affect otherwise suitable low noise devices from a few tens of Hz upwards (Lauritzen, 1965).

The choice of a FET for this work was determined by the availability of special low noise FET's of type 2SK146 and the dual matched pair version 2SK147 both made by Hitachi. The noise characteristics of these devices were compared with similar low noise FET's such as the U301, 2N4658, and were found to be superior.

4.2.3 NOISE IN FIELD EFFECT TRANSISTORS

The equivalent noise sources of a FET are shown in Figure 4.1 where the $\overline{e_n^2}$ and $\overline{I_n^2}$ are the voltage and current noise sources respectively. The typical spectral density function of these sources is shown in Figure 4.2 (Siliconix, 1985).

Part 2 of the graph shown in Figure 4.2 corresponds to the white noise component of the device due to the $g_m$ (mutual transconductance) of the FET, and is calculated (from Siliconix 1985) according to:
Figure 4.1. Equivalent FET noise circuit.

Figure 4.2. Characteristics of FET noise. Redrawn from Siliconix (1985).
At constant temperature, this type of noise is inversely proportional to the value of the mutual transconductance which can be increased by maximizing the drain current $I_D$ to near the saturation point $I_{DSS}$. The value of $g_m$ is proportional to the square root of $I_D$ which $E_n$ is proportional to $I^{-1/4}$ so, there is no advantage in going beyond this value. In addition, excessive heat dissipation reduces the effective $g_m$ and so increases the leakage current $I_g$.

Part 1 of Figure 4.2 refers to the flicker noise. This is the $1/f$ noise in the FET and it arises from the trapping of carriers in the Shockley – Read Hall generation recombination centers in the junction depletion region. These centres are the main source of reverse bias leakage current in the silicon diode. Referring to Figure 4.3 (from Kandiah and Whiting, 1978), generation centres represented by $X$ alternately emit a hole and an electron, and simultaneously fluctuate between a change in gate voltage or a true input signal. Thus, the channel current varies or flickers. The generation centres are due to crystal defects or impurities. The flicker noise is formulated as follows (Siliconix, 1985):

$$e_n = 4 K T \left( \frac{0.67}{g_m} \right) \times \left( 1 + \frac{f_c}{f^*} \right)$$  \hspace{1cm} (4.7)

Clearly, from the above equation the only variable which can decrease the flicker noise, except the temperature, is the value of $g_m$ which corresponds to the white noise component of the flicker noise.
Figure 4.3. FET Cross-section. Redrawn from Kandiah (1978).

Figure 4.5. Noise spectrum of the head amplifier.
The current noise \( I^2 \) in an FET is calculated as follows:

\[
I_n^2 = 2q I_g + 0.67 \times \frac{4K}{g_m} \times \omega^2 C_{gs}^2
\]

where the first terms of the equation is the Shot noise as shown in Figure 2 part 3, and the second terms corresponds to the thermal noise of the input impedance / admittance. The value of \( C_{gs} \) is about two-thirds that of the total input capacitance \( C_{gs} \).

Again, very little noise optimization can be done through the circuit design and most variables depend on the device chosen.

Another form of noise found in FET is "pop-corn" noise consisting of random bursts of almost the same amplitude and occurring below 10Hz. The origins of "pop-corn" noise are not completely identified but are believed to be generated by intermediate conduction at aluminum - silicon contacts, and also by contamination during the oxidization process during manufacture (Van Der Zeil, 1978).

4.3 LOW NOISE FET AMPLIFIER

In the design of the low noise amplifier careful consideration to the selection of the semiconductor component for the head amplifier stage was given as described above. The specially fabricated dual matched pair FET 2SK147 give at 1 kHz a spot noise level equal to 0.75 nV / \( \sqrt{\text{Hz}} \), equivalent to the Johnson or white noise produced by a resistor of 35 \( \Omega \) at 290 K and
a corner frequency of 3 Hz with a minimum factor \( n = 1.6 \) to 1.7 (Toshiba, 1989).

The circuit diagram of the head amplifier is given in Figure 4.4. The 2SK147 pair \( P_2 \) is configured in common source mode and the design is based on that of Pallottino and Vannaroni (1985).

To lower the SDF of the voltage noise by a factor of \( \sqrt{2} \) a dual matched pair was used to make use of the uncorrelated noise feature of this type of circuit (Toshiba, 1989). The resulting SDF of the current noise and the input capacitance are increased by the same \( \sqrt{2} \) factor.

The data sheets for this device show that it gives the best noise figure at \( I_D = 5 \) mA, that is, at the operating point where \( I_D \approx I_{DSS} \) and the transconductance \( (g_m) \) is highest for the supply voltage of 12 V which was used.

\( E_n \) and \( I_n \) are both temperature dependent so thermal shielding was needed, the device was build in three separate mild steel boxes. The first box contained the head amplifier transistors and first amplification stage; the second box contained the remaining amplification stages; the third box provided additional shielding and contained both the first and second boxes, the lead acid batteries, and the mu-metal shielding enclosure which contained the water samples and the electrodes. With this arrangement the non-differential head amplifier was isolated from any environmentally produced electrical interference including the 50 Hz mains fields and other fields produced by lifts in the building, fluorescent lights, electrical machines in the laboratory and the near-by computer room. In addition, the enclosures offered thermal isolation against air draughts and rapid temperature fluctuations. This is a particular advantage for low frequency precision and low drift measurements.
Figure 4.4. Circuit diagram of the head amplifier.
A common 50 Hz supply transformer and well regulated power supplies were found to introduce interference, noise and regulation ripple of the order of a few μV at the power lines. This was found to be inadequate for the present performance target so, the amplifier was supplied from two-12V, 6 VA lead acid batteries which introduced a power line noise of the order of only a few nV (Vandewoude and Vermanen, 1989). They were recharged when the amplifier was not in use and gave 3 hours continuous operation for each charge.

Referring to the circuit diagram in Figure 4.4, the input FET pair P2 is loaded by the resistor Rl and the FET pair P1 is configured as low-noise current-source which supplies the current needed to bias the P2 pair (Siliconix, 1990). In this way, any fluctuations on the power supply lines produce negligible effect on the drain current of the P2 pair.

The third battery, a 2 V, 0.6 VA lead acid battery turns-on the P1 pair which in turn permits a high value of bias resistor RB as compared with RF and thus gives a strong reduction in gain of the P1 pair and consequently there are negligible effects on the drain of the P2 pair.

Referring to the input high-pass filter RIN - CIN, the value of the RIN determines the input resistance of the amplifier and CIN is chosen to adjust the lower cut-off frequency of the amplifier. In addition the presence CIN blocks DC voltages, and drifts produced at the electrodes and also shunts the thermal noise produced by RIN.

The large capacitance of CIN can be quickly discharged via S1 avoiding in this way any long discharge time constants.

The operational amplifier OP-111 is an ultra low noise device having low bias current. It is a precision op-amp operating
in virtual-ground mode. This effectively places the \( G_{gd} \) (gate to drain capacitance) of the \( P2 \) pair in parallel with \( R_{in} \) without introducing magnifying factors due to gate-drain Miller effect (Sonde, 1973).

The gate-source capacitance \( C_{gs} \) does not contribute to the input impedance and the amplifier bandwidth because series feedback maintains a very low gate to source voltage in this frequency range.

Therefore, the theoretical value of the input capacitance is equal to \( C_{gd} \) which is equal to about 70 pF (Toshiba, 1989).

The overall gain of the amplifier and its frequency response were measured and found to be 40 with lower and upper cut-off frequencies of 0.1 Hz to 25 kHz respectively.

Additional gain up to a further 60 dB can be obtained if required with the additional amplification stages shown in Figure 4.4.

4.4 MEASUREMENT OF AMPLIFIER NOISE

The amplifier noise measurement were made with a wide band digital FFT analyzer, type ONOSOKI, which was connected to the output of the amplifier. In this measurement the noise generator was a metal film resistor, which could be assumed to have a flat noise power spectrum.

The RMS voltage spectrum measured with this known noise source resistance was then compared with the spectrum obtained with the input grounded. The current noise produced at the input of the amplifier could be neglected due to its very high input
impedance, leaving a main noise component consisting of white and flicker noise.

The mean square output noise voltage with zero source resistance equals:

\[ \overline{V_o^2} = 4KTR_n \quad (V^2 / Hz) \]  \hspace{1cm} (4.9)

The mean square output voltage due to a finite source resistance \( R \) equals:

\[ \overline{V_R^2} = 4KT (R_n + R) \quad (V^2 / Hz) \]  \hspace{1cm} (4.10)

where the \( R_n \) is the equivalent input resistance. From the ratio of the \( \frac{\overline{V_o^2}}{\overline{V_R^2}} \) \( R_n \) equals:

\[ R_n = \frac{R}{(\overline{V_R^2} / \overline{V_o^2} - 1)} \]  \hspace{1cm} (4.11)

For the frequency band 1Hz to 20 kHz the measured average of the peak of the noise spectrum was plotted and is shown in Figure 4.5.

For small values of source resistance \( R \), the flicker noise component dominates at low frequencies; a measurement of \( V \) rms was made at 1Hz. At mid-band frequencies the differences in the noise voltages were measured and are also shown in Figure 4.5, and these
were later used to calculate the equivalent input noise resistance.

The equivalent input noise resistance at 1 Hz was calculated using the ratio of the mean squared noise voltage at low frequency to that at mid-band:

\[
\overline{V_{n1}^2} = 4KTR_{n1} \quad (V^2 / Hz) \quad (4.12)
\]

\[
\overline{V_{nR}^2} = 4KT(R_n + R) \quad (V^2 / Hz) \quad (4.13)
\]

and from the ratio of these two equations

\[
R_{n1} = (R_n + R) \frac{\overline{V_{n1}^2}}{\overline{V_{nR}^2}} \quad (4.14)
\]

where \(R_{n1}\) is the equivalent input noise resistance at low frequencies:

4.5 RESULTS

Using the method shown in section (4.4) and using a typical value for the source resistance \(R\) of 47 \(\Omega\), the equivalent input noise resistance was calculated for the amplifier with a gain of 40 at 1Hz \(R_{n1} = 4800\) or 2.8 nV / Hz\(^{1/2}\) and at 10kHz \(R_{n1} = 47\) \(\Omega\)
or $0.86\ \text{nV} / \text{Hz}^{1/2}$.

The white noise level expected would have been that produced mainly by the FET pair $P_2$ which contributes $0.75\ \text{nV} / \text{Hz}^{1/2}$ and the $R_F$ ($10\ \Omega$) which connected to the sources of the $P_2$ FET pair and ground. For the resistor $R_F$ the noise is equal to $0.4\ \text{nV} / \text{Hz}^{1/2}$, this makes the total of $0.85\ \text{nV} / \text{Hz}^{1/2}$ any additional noise may be due to the first FET pair and from the physical layout of the circuit of the amplifier.

### 4.6 COMMENTS

In order to achieve this low noise performance special consideration was given to the construction and lay-out of the amplifier components and particularly to wire bonding and grounding. In order to avoid ground-loops, every ground wire was terminated at the main ground junction, and all discrete devices were decoupled from the power supply with an $RC$ ($R=1000\ \Omega$, $C=100\ \mu\text{F}$) low pass network. These are not shown in the circuit diagram of the amplifier Figure 4.4.
CHAPTER V

ELECTRODE CHARACTERISTICS

5.1 INTRODUCTION

The water samples were measured by inserting two electrodes into the water and these were connected by short leads to the input of the amplifier described in Chapter 4.

In the present Chapter, the electrical properties of electrodes are outlined, with special reference to those types of electrode used for this work, their electrical characteristics, and the noise which they contribute to the instrumental noise of the overall measurement system.

5.2 ELECTRICAL PROPERTIES OF ELECTRODES

When a metallic electrode comes into conduct with an electrolyte, an ion / electron exchange occurs. There is a tendency for metallic ions to enter into solution and a tendency for ions in the electrolyte to combine chemically with the metallic electrode. A net charge is transferred, a double layer is formed and the electrode is said to be polarized (Geddes and Baker, 1989).

The presence of a charge distribution at an electrode - electrolyte interface produces a capacitance. Warbug, (1899, 1901) was the first to investigate the electrode-electrolyte interface and develop an electrical model for in terms of resistance and capacitance as a series network.

The magnitude of the R and C components is dependent on the particular electrode type, the surface area, the surface
conduction, the electrolyte, the frequency, and the current
density used in a measurement with the electrodes (Geddes and
Baker, 1989). This last factor was negligible for the present
experiments as the signal levels were in the nV to μV range giving
signal currents of the order of fA to pA.

The voltage developed at a single electrode-electrolyte
interface is called the "half-cell potential", the "half"
corresponds to one of each of the pair of electrodes which must be
involved in a practical system. The potential of a single
electrode cannot be measured, but the electrode potential of a
specific metallic electrode can be specified with respect to a
hydrogen electrode which is the standard electrolytic reference
potential.

5.3 MEASUREMENTS OF ELECTRODE IMPEDANCE

The electrode-electrolyte interface can be modelled as three
series impedances thus:

\[ R_b \quad Z_e \quad R_e \]

where \( R_b \) is the bulk resistance of the electrolyte which is
a function of electrode geometry and proportional to the specific
resistance of the electrolyte (Hary and Bekey, 1987).

\( R_e \) is the resistance of gold electrodes which was negligible
\( Z_e \) is the electrode-electrolyte interface impedance, and
is a frequency dependent quantity and which can be modelled as
follows:
where $R_e$ and $C_e$ are both frequency dependent quantities.

The values of $R_e$ and $C_e$ can be measured with a LCR bridge, however in some LCR bridges the static potential of the electrodes and small fluctuations produced in them may disturb the balance condition. The circuit shown in Figure 5.1 was built for measuring the $R_e$ and $C_e$ for the two gold electrodes in a 0.9 % saline solution.

Referring to Figure 5.1, the operational amplifier is configured as a current amplifier. The signal generator in series with the electrode-electrolyte interface constitutes a current source. On the oscilloscope, a Lissajou figure was obtained and this allowed the direct measurement of the impedance $Z_e$ and the phase angle $\phi$ of the signal.

The amplitude of the signal generator (type-Level G2) was kept constant at 100 mV (rms) over the frequency range 10 Hz to 10 kHz.

The graph shown in Figure 5.2 shows the value for $Z_e$ plotted against frequency $f$ both are on logarithmic scales. At high values of frequency $f$, $Z_e$ is small enough to be neglected so a direct reading of the electrolyte resistance $R_b$ can be made (Block, 1968). If $R_b$ is subtracted, a constant phase versus frequency relationship is observed for $Z_e$ which is a characteristic of the particular electrodes used (Geddes and Baker, 1989). From the same graph in Figure 5.2, the straight line relationship of $Z_e$ (excluding $R_b$) versus frequency on a log-log plot is also observed. This represents a power law from which the
Figure 5.1. Diagram of the circuit measuring the electrode impedance.

Figure 5.2. Electrode-Electrolyte impedance.
slope of the graph of $Z_e$ is proportional to $f^n$ where $n$ is a constant.

It has been approximated by Geddes (1972) and Block (1968) that the values of $Re$ and $Ce$ are almost equal. Therefore, from the formula

$$Z_e = \sqrt{Re^2 + Ce^2}$$ (5.1)

values for $Re \approx Ce$ can be estimated.

It should be noted that accurate measurements of the electrode-electrolyte impedance and electrolyte resistance are not necessary since the concentration of the solution, and the electrode separation are variable quantities from one experiment to another and are negligible compared to the amplifier input impedance. Measurements were made to determine the electrical characteristics of the water samples used, and to estimate the noise generated at the electrode-electrolyte system.

5.4 RESULTS

The minimum noise which the electrodes can contribute to the system is that of the electrolyte and that of the resistive component of the electrodes. From the measured values this $Z_e$ at 10 kHz equals 0.5 kΩ and from the expression (5.1) $Re = 353 \ \Omega$ noise contribution can be formulated by Johnson noise (Godin et al., 1991) and equal to 2.3 nV / Hz$^{-1/2}$. From the measured values the resistance of the electrolyte for the particular electrode
arrangement was measured to be 1.4 KΩ, thus producing a noise of 4.7 nV / Hz⁻¹/₂.

5.5 COMMENTS

For the gold wire electrodes used, the half-cell potential in physiological saline is + 1.50 V (Strong, 1973), but because two electrodes of the same metal were used their differential potential is ideally zero (Geddes and Baker, 1989).

In practice, small potentials are to be expected even for two electrodes of nominally the same material. These potentials are not stable and give rise to signals which are low frequency non-periodic fluctuations of the order of 1 mV and have a duration shorter than 100 msec (Flasterstein, 1966a, 1966b); (Kramer, 1983). The main source of this noise is contamination on the surfaces of the electrodes.

The biggest fluctuations in amplitude found at the instant a liquid first comes in contact with the electrodes. This is the time when the electrode potential is generated. Resistive as well as capacitive loads are present at the input of an amplifier, connected to the electrodes.

Voltage fluctuations were detected due to ionic drifts in the liquid, or bulk movement of the liquid. The glass beakers used for these experiments were stored in a hot oven at 80 °C. At the time they were used their temperature was still, higher than that of the water under investigation. Convective motion was observed in the water and this resulted in low frequency voltage fluctuations until the water motion ceased, usually within 10 to 20 sec.
Mechanical vibrations of the building and environmental acoustic noise were found to couple to the electrodes; these vibrations gave electrical signals at frequencies at the mechanical resonance of the electrodes. Accordingly, the experiment was set up on an acoustic absorbing bench made from layers of cork tiles 2mm thick and plastic foam 4 cm thick. Additional voltage fluctuations were found to be due to impurities in and on the surfaces of the electrodes. The gold electrodes used were of 99.99% purity. The removal of surface contamination by salts and grease from handling were a part of the experimental procedure.

As a part of the general procedure, the electrodes when not in use were shorted together in clean water and kept short circuited until at least 30 sec after they had been dipped into the sample of water or potency being measured. This follows the recommendations by Geddes and Baker (1989). After each experiment, the electrodes were cleaned with an alcohol flame, dipped into distilled water and flamed again for 15 to 20 sec. The role of the flame was not only to keep the electrodes in a sterilized condition but also to break up by this heating any ordered or vicinal water bonded onto the gold surface.

The minimum white noise contribution of the electrodes has been found to be at least three orders of magnitude higher than that produced by the low noise amplifier. Thus, the overall sensitivity of the detection system is limited by the noise produced by the electrodes and the electrolyte; the best case of that is \(5.2 \text{nV} / \text{Hz}^{1/2}\).
CHAPTER VI

EXPERIMENTAL WORK

6.1 INTRODUCTION

In this chapter, the procedure used to potentize water for the present work with the imprint of various substances, that is for the preparation of homoeopathic remedies, and the procedure to potentize water with magnetic fields is outlined.

The experiments described in this chapter were made with particular reference to existing theoretical models proposed for potentized water in order to attempt to obtain information which might test their respective variabilities.

As mentioned earlier an attempt was made to repeat Ludwig's experiments involving homoeopathic remedies and to extend his method to magnetically potentized water. Ludwig offers no scientific explanation concerning any "memory" mechanism in water or other liquids nor does he describe his experimental setup in exact detail. Therefore, theoretical assessment of his particular experimental work cannot be given but it was susceptible to the experimental validation by the rest of the experiments described which were developed by the writer and are based on proposed models for potentized water. Those in turn are based on the clinical effects of homoeopathic potencies. Therefore, the formulation and specifications for each particular experiment are restricted to the information available in each case.

78
6.2 THE PREPARATION OF HOMOEOPATHIC AND MAGNETIC POTENCIES

For this work, the Mother tinctures of thirty substances were kindly provided by the Homoeopathic Institute of Brazil. Serial dilution were made in volumetric bases in the fold of 100 (1CH) in double distilled water in the manner described in section 1.7. Tsouris (1991) has given an extensive review of the preparation of homoeopathic potencies with special reference to the guides given by different pharmacopoeias, and alternative methods of preparing homoeopathic remedies.

Homoeopathic remedies and magnetic potencies were prepared for the present work in silica-glass phials which were cleaned with triple distilled water and left in the oven at 80 °C to dry in air. Remedies were made in a clean air environment away from dust and strong smells, and strong sunlight. In addition, attention was given to ensure that strong AC or DC magnetic fields were not present during the process of potentization such as those produced by electric motors or the personal computer in the laboratory. For every experiment made, new potencies were prepared, and if a large quantity was made then attention was given to ensure that the remedy was not mishandled in any way.

The process of succussion originally involved hard impacts on the binding of a thick book on the bench. The force of succussion was measured on an ordinary weighting scales and found to be 10 Kg. The time constant of the scale's response was not measured. Ten succussions were given for every potency, using a constant force, and the frequency of succussion was 1 per sec.

The process of serial dilution was made volumetrically in the fold of 100. Thus, for preparing 5ml of a potency 4.95ml of water was used and 0.05ml of mother tincture was added to water followed by ten strong succussions. For the second dilution 0.05ml is taken
with a clean pipette and added to 4.95ml of water. The process was repeated until the desired potency is made.

Magnetic potentization was carried out using the alternating magnetic field produced by a coil of 1000 turns of insulated copper wire of 24 SWG. The coil was connected to the terminals of a signal generator capable of producing 35 V p.p across the coil. The water sample was kept well away from the coil and the signal generator until amplitude and frequency had been set. The water was then brought in front of the coil and was succussed 10 times. This potency could retain its information when frozen, but would not potentize in the absence of the geomagnetic field. The same procedure was followed if multiple frequencies were required to be imprinted into water.

6.3 EXPERIMENT I

6.3.1 INTRODUCTION

The aim of this experiment was to reproduce Ludwig's results on homoeopathic remedies, that is to be able to characterize different potencies in terms of their frequency spectrum.

6.3.2 METHOD
Figure 6.1. Experimental setup for detecting coherent signals in water.
The experimental setup as described by Ludwig and followed by the author is shown in Figure 6.1. Homoeopathic remedies potentized in double distilled water were prepared to the 50 C potency by the writer by the method described in section 6.2.

The remedy was then placed inside the shielding enclosures. In the apparatus the potentized water was activated acoustically with random noise. This activation was a procedure of Ludwig's protocol. The noise voltage was generated in the spectrum analyzer used (an Onnosoki type 2048) and was available at 30 V p.p.

The random noise acoustic waves were produced from this output using a polyvinylidene difluoride (PVDF) piezo film produced by Kynar Piezo Film. This piezo transducer was type SKM21. It was of dimensions 5 cm height, 2 cm width, and 0.5 mm thickness. The transducer was water proof so it could be dipped directly into the water sample being measured. The volume of the potency sample was standardized to 50 ml and placed in a 75 ml glass beaker. The piezo transducer was supplied coated with silver paint. This provides some factor of shielding but was inadequate since the electrical signals used to excite the piezo could also be detected at the electrodes. In order to avoid noise interference the piezo film was enclosed within 0.3 mm thick brass foil which was soldered around all joints. In order to achieve maximum acoustic coupling between the water sample and the piezo, the transducer was covered with a thin layer of silicone grease to couple the signals through the brass cage.

At this stage of the work acoustic waves were used to irradiate the gold electrodes. They resulted in increased electrical noise as a result of the small mechanical vibrations of the electrodes. In order to eliminate these vibrations, the
Figure 6.1. Experimental setup for detecting coherent signals in water.
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At this stage of the work acoustic waves were used to irradiate the gold electrodes. They resulted in increased electrical noise as a result of the small mechanical vibrations of the electrodes. In order to eliminate these vibrations, the
Photograph c):
(From left to right) shows the toroid, the steel screening box and the signal generator (far left) used for potentizing water or driving the toroid.

Photograph d):
The top view of the steel shielding box. (From left to right) The outer black enclosure, is the steel box, the internal metal box contains in turn the mu-metal box, the gold electrodes attached to a stand, and the head amplifier. In the far right the lead acid batteries are shown one on top of the other.
gold wire electrodes were wrapped around two glass rods 3mm thick so that the electrodes were 1 cm apart and 2 cm below the surface of the water sample. The noise source was synchronized so as to start at the moment the spectrum analyzer was seeking to acquire data.

6.3.3 RESULTS

The spectrum analyzer output failed to show any significant results in the form of coherent resonances as reported by Ludwig. A sample graph of the output compared with the control untreated water is shown in Figure 6.2.

The same experiment was repeated using different spacings between the electrodes, and different electrodes (Ag/AgCl, and Al), but there were still no significant observations.

Homoeopathic potencies were considered as complex sources in respect of their frequency spectrum, the variables involved in the process of potentization, and origins of the mother tinctures from which they were prepared. In order to eliminate these variables, the experiments were continued using magnetically prepared potencies. In this way, water samples could be prepared and tested in large numbers, with the variables concentrated only in the instrumentation part of the experiment. Every remedy was magnetically potentized at a single frequency, away from any of the harmonics of the 50 Hz mains supply systems.

With the experimental set up as described above, some observations were made and shown in Figure 6.3. The traces shown refer to a) unpotentized water (b), water potentized at 1.00kHz, and serves as a control for tracing c) which is the same sample of water into which the frequency of 1.10 kHz has been imprinted. This has been cited in the book Ultra High Dilution (Smith C.,
Figure 6.2. Top trace shows the control double distilled water. Bottom trace shows noise of NaCl potentized at 50 C.
Figure 6.3. The lower tracing a) shows the control sample
b) shows a magnetically imprinted resonance at 1kHz
c) shows water which has been exposed to 1.0kHz and 1.1kHz.
6.3.4 CONCLUSION

The initial objective of repeating Ludwig's experiment, that is to detect coherent signals with a frequency spectrum related to homeopathic remedies has failed. However, some indications of coherent electrical activity in magnetic potencies has been detected.

6.4 EXPERIMENT II

6.4.1 INTRODUCTION

According to Del Giudice (1991), the establishment of coherent domains in water could result in weak emissions of electric fields as a result of coherence. The aim of this experiment was to detect those electrical signals involved in magnetic potencies and evaluate their electrical characteristics.

6.4.2 METHOD

The experimental set-up and procedures for this experiment were the same as described in experiment I, but without the acoustic excitation.

The typical background noise levels of several different mineral waters bought from a supermarket are given in Appendix I. The noise levels were found to be related to the salt concentrations in the water samples according to the different analyses as specified in their labels.

The "staircase-shape" spectrum of the noise from water at
different frequencies as produced by the spectrum analyzer was repeated when a resistor, capacitor network was connected to the input of the amplifier, thus it must have been an instrumental effect.

Clearly, if coherent domains are involved in water and have specific arrangements in space as a result coherent coupling then at any two arbitrary points within a potency sample there should exist a potential difference. The likely spacing between domains have not been formulated by Del Giudice nor are their overall shapes or arrangements if any. It became evident that the only way to detect such weak voltages was to increase the sensitivity of the amplifier.

6.4.3 RESULTS

The sensitivity of the amplifier, and its attendant sensors, is limited by the noise produced at the electrodes. However, to be able to investigate further, the FFT analyzer was set to perform 4096 averages on the incoming signal. The maximum sensitivity achieved with this method was $\approx 100$ pV. A typical display for water potentized in this case at 4165.6250 Hz with this frequency resolution is shown in Figure 6.4. This particular frequency component was chosen to be far away from any harmonic component of the mains 50 Hz. The bandwidth of the spectrum analyzer was limited to 625 Hz in order to decrease noise.

However, with the set-up described in this section, there was an indication of a frequency component imprinted in water as shown in Figure 6.5. The output signal could only be detected after 128 averages. Referring to the Figure 6.5 the upper trace is for untreated water, and the lower trace shows the frequency component observed at 913.1250 Hz. The noise bandwidth was 125 Hz, and the
Figure 6.4. The trace shows noise at 100pV resolution. The head amplifier gain was set to 200.
Figure 6.5. The top trace shows the power spectrum of untreated water, and the bottom trace water treated with a 905.1250 Hz magnetic field. • frequency marker is the same in both traces.
resolution 0.0015 Hz. The spike in the middle of the trace is produced by the spectrum analyzer, and was always observed when using its zooming facility.

6.4.4 CONCLUSION

The experiment was not repeatable, and it may have been the result of some leakage signal through the mains wiring from a signal generator nearby but outside the shielding enclosure. Coherent signals were observed but once again in a temperamental manner. Referring to Figure 6.5 resonances show the extreme sharpness of the very high degree of coherence which must be present.

6.5 EXPERIMENT III

6.5.1 INTRODUCTION

Further experiments involved the investigations of the acoustic properties of the potencies. The idea introduced in Chapter I, was that if a large number of coherent or helical structures were present in the liquid, slightly different absorptions of acoustic waves should also be a property of potentized water. This method attempts to test for any alterations in the molecular structure of the liquid in the low frequency range. The structural relaxation time of water is in the order of $10^{-12}$ sec. but the instrumentation built was limited to frequencies of up to 20 kHz.
6.5.2 METHOD

The spectrum analyzer was set to sweep from 10 Hz to 2 kHz, and synchronized to acquire data simultaneously. The water samples were exited with a SKM21 piezo, and the acoustic waves were detected by an identical piezo which was placed 5 mm from it. The experimental arrangement shown in Figure 6.6 was too sensitive and was extremely difficult to perform it repeatably. The reasons for this were, first the amplifiers were extremely sensitive to ambient audio noise. This problem was overcome by covering the mu-metal shielding box with 5 cm plastic foam all around. Secondly, a problem involving the beaker containing the water. Since standing waves were produced at the surface of the beaker the dimensions of the beaker were significant and thirdly the depth of water had to be exactly the same every time the experiment was performed. This was overcome by holding firmly both piezos on a wooden stand, and injecting 500μl of the potentized water between the piezos as shown in Figure 6.6.

6.5.3 RESULTS

The experiment failed to show any discrete peak of absorption at the frequency to which it had been potentized, but it did produce some quite definite peaks at certain frequencies for ordinary water, and different peaks for water which had been potentized. These are shown in Figure 6.7 and Figure 6.8. It is clear that such a complicated spectrum makes it very difficult to produce any significant interpretation in the absence of a theory of water memory, especially in this low frequency region.
Figure 6.6. Experimental setup for the detection of acoustic resonance in water.
Figure 6.7. The top trace shows the acoustic absorption spectrum of tap water. The bottom trace shows the frequency response of the piezos.
Figure 6.8. The top trace shows the frequency response of deionized water. The bottom trace shows the frequency response of the same water treated with 1230.0Hz magnetic field.
6.5.4 CONCLUSION

The expected sharp absorptions at particular frequencies failed the test of successfully measuring the frequency which had been imprinted into the water sample. However, broad band resonances have been obtained in potentized water and may be due to dense ordered clusters in the liquid.

6.6 EXPERIMENT IV

6.6.1 INTRODUCTION

The aim of this experiment was to investigate the noise properties of potentized water, and whether the on-off appearance of coherent signals could be justified.

6.6.2 METHOD

Further considerations have been given to the Del Guidice theory with special reference to his proposed microscopic coherent domains involved in coherent water. A domain having a size in the order of a 300 μm would result in a velocity reduction from 300 Mm s\(^{-1}\) to 1 m s\(^{-1}\). If the wavelength in a coherent system is a constant parameter and the frequency and velocity are variables, then the frequency is reduced to the kHz range. At a distance from the electrodes of 1 cm the resulting wave at the electrodes with many radiating domains throughout the water sample will appear as random signal at the electrodes. To detect this signal one would either have to confine the potency in a 300 μm width by 300 μm height cell, and the minimum possible depth so
Photograph a):
The gold electrode wires, mounted on a specially fabricated perspex stand, immersed in water.

Photograph b):
The toroid used for the generation of magnetic vector potential, used for potentiizing water or activating the water samples contained in the enclosure on the right.
that coherent domains are restricted to two dimension coherence. However, at these small distances, there is a risk of actually erasing the bio-information.

As an alternative, the noise properties of water and potentized water could be examined. If one contains the bio-information this would result in a different noise spectral density.

An experiment was set up in the shielding enclosures with no acoustic excitation using a pair of electrodes, one copper and one of gold. The two different metal electrodes were used in order to provide a small d.c. bias signal to the sample and giving asymmetries to the sample of water. The sample was excited with a magnetic vector potential produced by a toroid which was placed outside the screening enclosures. The toroid had 333 turns, a mean diameter of 101 mm, a cross-section 25x3 mm, the core had a relative permeability $\mu_r = 87$ and it was driven with a voltage $10\text{Vp.p}$ and a frequency of 1.000 kHz as recommended by Smith C. (1994b). The overall gain of the amplifier was set to two thousand. The samples of data were collected with the data acquisition system which is described in Appendix II. Ten samples of data from untreated Perth water, and ten samples of data from the same water which had been potentized in the same beaker at 1.000 kHz were collected and stored on a floppy disk.

6.6.3 RESULTS

The Fourier transform of the data was calculated with "Easyplot" software, and the mean and standard deviations of the frequency components were also calculated. Figure 6.9 shows a plot of the mean and standard deviation of water and "treated" water. The plot for potentized water shows large fluctuations
Figure 6.9. The mean and the standard deviation of the frequency components of water treated with 1kHz and a control sample.
about the mean. The mean for the 1kHz treated water is larger than that of the control indicating the existence of another additional frequency component. The standard deviations of treated water is smaller than that of the control which is a statistical expectation. Since, one is dealing with a Poisson distribution, the mean is proportional to the mean number of events \( \bar{N} \) and the standard deviation is proportional to \( 1/\sqrt{\bar{N}} \). The values shown in Figure 6.9 give a change of standard deviation which is approximately the square of the mean.

6.6.4 CONCLUSION

From the statistical treatment of the frequency spectrum of potentized water it has been shown that coherent domains in water is very likely to be spaced randomly in a potency or to be in a constant motion inside the liquid. Further experimentation is required to establish the probability distribution of water and potentized water, which may also explain why coherent signals were detected on an on-off basis.
CHAPTER VII

DISCUSSION

The objective of this work was to detect coherent signals involved in potentized water, and to establish the existence of any coherent or memory mechanism in the liquid.

The work was initiated after Ludwig's scientific opinion published 1989. The many publications referring to a memory property in water have been discussed, a large number of which appeared in homoeopathic journals. The author believes that both homoeopathic remedies and magnetically potentized water are closely related, in terms of memory mechanisms. This is based upon the clinical effects found by C.W. Smith, where hyper-sensitive people can have their allergic symptoms relieved or reactivated with both homoeopathic remedies and magnetically prepared potencies being frequency specific to a particular patient. In addition, homoeopathic practitioners have been using remedies prepared in static magnetic fields, electric currents and X-rays. C.W. Smith has shown that not only can static fields potentize water, but so can alternating fields, with symptoms being frequency specific to a particular patient. This concluding remark is made by the author and not by Ludwig. In fact Ludwig had no bases to relate homoeopathic remedies with a particular frequency spectrum which could characterize a remedy. In addition, there was no evidence of homoeopathic remedies having the property of sustaining coherence within a certain molecular arrangement but instead homoeopaths believe that water is able to "copy" the shape of molecular structure of the solute so that it acts chemically and not as result of coherence on a living system. This raises the
question did Ludwig obtain a specific frequency for each homoeopathic remedy with his experiment or was it an artifact?.

In physical science, most materials are characterized by their chemical and molecular structures, where relevant information concerning their chemical properties is formulated and supported in their physical quantities, for example chemical analysis by spectroscopy.

This is not the case for liquid water, in fact a molecular structure for a large number of water molecules is not established. Specifically, there are a number of models proposed for liquid water but none explain all its physical properties in full. This is due to the hydrogen bonds involved between the water molecules which make it so flexible in terms of its structural shapes and arrangements.

Proposed structures for potentized water and memory mechanisms which have been reported are even more ambitious. This is because, those models are mainly formulated to justify the clinical effects of the liquid, and little or no attention is given to the physics of the molecular structure of the water. However these works cannot be disproved since the molecular structure is so complex that little scientific argument can be made anyway.

The author, in looking at this problem from an engineering point of view had to translate a large amount of information related to clinical effects, and molecular arrangements into the bounds of an experiment confined within electronic engineering and its practical engineering limitations.

First, the procedures of potentization had to be investigated in terms of the methods available and the exact processes involved in the activation of water. An extensive review of this had already been given by the author Tsouris (1991). To find out the exact
process used in potentization, the author contacted G. Vithoulkas, a world renowned Greek homoeopath, and founder of the Athenian School of Homoeopathy. As a result, he had the details of potentization explained and demonstrated by his pharmacist M. Phylianos. The magnetic preparation potencies was carried according to C.W. Smith the first person to systematically potentize and clinically test water with alternating magnetic fields. Smith C. regards the magnetic field or succussion as providing a format to the water and the magnetic vector potential as the carrier of the bio-information.

The process of succussion in potentisation cannot amplify the clinical effects, but serial dilution and succussion make a potency more specific in terms of its clinical effects. This implies that high homoeopathic potencies should contain more specific or narrower bandwidth frequencies, this is not the case for magnetically potentized water. In terms of experimental arrangement it is recommended that magnetic potencies of single frequencies rather than homoeopathic remedies should be investigated, and the ultimate test should be that a frequency potentized magnetically can be read out under double-blind conditions.

The author has reviewed possible molecular structures of liquid water, in order to define within the liquid possible electric field generators and to relate liquid water to a model comprising a lot of small signal generators and the electrodes as passive antennae within a complex electric field environment. The author has also reviewed the properties of water at the interface with the electrodes which are regarded as active components coupling with interfacial structures in water. This, according to the literature cited, justifies the use of gold electrodes and establishes the cleaning process used for the electrodes before
and after the experiments.

However, when the electrodes are in contact with an electrolyte or any liquid, they are not just passive dipole antennae, but act in accordance with the electrochemical properties of the medium in which they are placed. Information on the electrical properties of particular electrodes can establish the limitations of the system in terms of its sensitivity and frequency response. The author, without knowing the oscillation strengths involved, nor the degree of coupling to these coherent sources made all the instrumentation circuits as sensitive as possible as the only way of having the best signal to noise ratio achievable with present technology. The head amplifier was single ended and not a differential instrumentation amplifier for the following reasons, 1) The environment had been made free from electrical interference by shielding, 2) only two electrodes were required and any alterations of the electrode impedance due to ionic drifts or movement of the electrodes would result in a common mode rejection ratio degradation. Special attention was paid to the low noise design for the detection and amplification circuits used, but no provision was made for the reduction of noise originally in the liquid since this might contain the wanted signal. The elimination of noise produced by the electrodes would involve chemical processes which in turn could effect the homoeopathic properties of the potency. Such effects could result from an etching process at the electrodes before use or, the addition of strong electrolytes to the remedies which in turn would reduce the impedance of the medium and electrode-electrolyte interface resistance.

Water is sensitive to magnetic fields especially if the environment also provides an acoustic and a static magnetic field component. An ideal experimental environment was needed in which
the magnetic fields both static and alternating were highly attenuated. The author designed and built the shielding enclosures, and has described their shielding mechanisms and design in Chapter 3. Such high performance enclosures are not described in the literature. The experimental setup and instrumentation built to characterize the electric and magnetic free environment also had to be designed by the author. The magnetic SE was measured and found to be in the order of 70 dB at 50 Hz. Given that there would be a magnetic field of 50 Hz in the laboratory of the order of 10µT, this would result in an internal field of less than 3 nT. This is well below the level at which water will potentize, and is just below the field at which highly sensitive patients will react to a frequency to which they are hyper-sensitive (Quboa, 1990).

Initially, considerations for the detection system was directed to imitate in some way a biological system. This in turn is very hard to obtain since the full electrical function of a biological system is not yet formulated. In addition, any attempt to imitate with electronic or other means a biological system would have to be confined to very general properties so that it would have been applicable to any biological system. This could only be attempted if at least the mechanism of the biological system to decode bio-information was known. However, the approach was general and the methods used in common biomedical engineering procedures were used.

The gold electrodes could take specific structure when flamed, so in a way they were similar to vicinal water structure or to that inside the cell wall. Alternatively, microelectrodes could have been used in an attempt to interface with small coherent domains but again the electrical characteristics of the microelectrodes would have restricted the sensitivity and the frequency bandwidth
of the measurements. In addition, if experiments were performed in a medium with dimensions in the order of 100 μm or that estimated for a single coherent domain, then one would run the risk of erasing the bio-information if more than one domain was involved in its storage. One could consider the use of biological cells as transducers and microelectrodes attached to the cells, but this is an experiment which would need good interdisciplinary laboratory facilities and the outcome could be the interpretation of the bio-information of the cell and not the bio-information in water. Eventually such experiments will be needed to understand how cells read the bio-information in a potency, but not before the bio-information contained in a potency can be read accurately and reliably.

The experimental set up and experiments themselves were very difficult to perform repeatably, especially the acoustic absorption measurements. Over the frequency range from nearly d.c. to nearly 2kHz many complex spectra were obtained as shown in this thesis.

The resonances shown in Figure 6.5 are typical of what were obtained but the extreme sharpness of some peaks indicates the very high degree of coherence which must be present. This was measured to be 0.4 Hz in 1kHz corresponding to a Q of 2500. In previous work, the author had designed and constructed an analogue spectrum analyzer, but this had the weakness that it could resolve only 4 Hz in the 20kHz bandwidth.

A spectrum analyzer made by Onosoki was rented for a period so as to have better resolution available. This instrument did not have the capability of storing the data in a universal format so that additional analysis and statistical treatment of the data could not be carried out. For this reason, a data-logger system was built to use commercially available software for
further examination of the data relating to these properties of water.

The impressions of these results are:

1) The best low noise techniques are adequate,

2) The time required to detect a 1 kHz sine wave on the basis of a Q of 2500 is 2.5 seconds for 98% of the resonance build up, or 0.4 seconds for a build up to 37%. To scan 0.4 Hz in 0.4 seconds is a scan rate of 1Hz/s or 10000s to scan 10kHz which is nearly 3 hours.

From the experience gained in this work, it is concluded that coherent signals in water do exist, but it is speculated that they are present on an on-off basis. The techniques used were not sufficiently sensitive for the phenomena to be observed in this way. The difficulties in getting repeatable results might be due to some particular order or randomness in the arrangement of coherence domains in water which do not have to show coherence beyond the confines of an individual domain, although Del Giudice considers it possible for them to communicate through the Josephson effect. This might require some form of external stimulation.

To overcome this problem it is necessary to regard coherence domains as isolated oscillators, randomly spaced throughout the liquid. A wave in a coherent medium has a velocity lower than it does in free space, because it acts only on the entire domains and not the individual water molecules. The interactions of each domain with the electrodes could equally well be represented by random in-phase signal due to the different distances waves from different domains travel until they reach the electrodes.

The data obtained for the frequency spectra of noise from water and "treated" water showed large deviations in the mean
and standard deviation for the "treated" water compared to the untreated control water.

The standard deviation should decrease as the square root of the increase in the mean if a Poisson distribution describes these signals from the water.

The criterion of accurately retrieving a frequency imprinted magnetically into water were only met with difficulty and on a few occasions. The problem was reproducibility in the measurements, this may be an intrinsic problem with water and homoeopathic remedies in that the "memory" may be erased on "read out", this would present no problems for their clinical use.
The following paragraphs represent the writer's criticism of the various molecular structures and "memory mechanisms" so far proposed for potentized water by various authors as have been outlined in Section 1.3 - 1.6 of this thesis. They are written in the light of the results of the experiments reported in this thesis.

First, is a comment in respect of the Barnard and Stephenson hypothesis which suggests that helical structures are formed by water molecules in homoeopathic remedies as a result of serial dilution and succussion.

Given that homoeopathic remedies range from very complex substances in terms of their chemical composition to the simplest of substances, (that is chemical elements such as copper, gold, silver, phosphorous, arsenic and selenium), it is impossible to represent all chemical compounds merely in terms of different lengths of a simple helical water structure. For example there are not enough parameters to represent the possible arrangements of the 92 chemically distinct (naturally occurring) atoms, or for example the hundreds of chemical arrangements from which proteins are constructed by selection from a list of 20 different amino acids; let alone the $4^{500}$ different nucleotide sequences theoretically possible in the DNA of an average gene.

The Smith C. hypothesis described in Section 1.4 also suggests that a helical structure may be involved in magnetically prepared potencies because this way it could
couple efficiently to an applied magnetic field and act as a resonant delay-line. Ice can have a pentagonal structure but to close the pentamer ring requires a bond bending of 17.5°. If the pentagon is not closed but the chain is allowed to continue growing, it will develop into a helix. Unfortunately, this hypothesis requires a very long helix to be produced in water if it is to represent water potentized at very low frequencies. For example, to represent water potentized at 17 mHz would require a helix $8 \times 10^8$ m long and this would involve all the molecules in 1 ml volume of water (Smith C. et al., 1985b). If such structures actually existed, they would have been observed already in the many diffraction experiments carried out on water.

In Vithoulkas hypothesis in Section 1.5, it is suggested that the molecules of the "mother tincture" of a homoeopathic remedy are surrounded by a shell of hydrated clathrate. In the case of a homoeopathic remedy prepared from a "mother tincture" derived from a plant extracts for example, this would contain many different chemical compounds and clathrates would need to be formed for each one of them. During the process of succussion, it is postulated that the clathrate-cage molecules may escape from the clathrate due to differences in inertia, thus leaving empty clathrate-shells and freeing a molecule capable of forming a new clathrate in the solvent water. However, these clathrates would not be solid crystalline structures and their formation may in
any case be possible with non-polar substances. An empty clathrate would collapse under surface tension forces until balanced by the pressure of internal gas, and this only until the gas dissolved in the water.

For example, the surface tension of water is 72.2 N m\(^{-1}\). In experiments on succussion already described, the force of succussion was measured with a spring balance and found to be of the order of 10 kg wt. This is a force of 98 N, and if applied to the end of a tube of cross section 1 cm\(^2\) would represent a pressure impulse of almost 10\(^6\) Pa (N m\(^{-2}\)); that is in effect a shock wave of about 10 atmospheres pressure which is quite reasonable.

The excess pressure (P) in a bubble (of radius r) in water due to surface tension forces (T) is given by,

\[ P = \frac{2T}{r} \]

A pressure of 10\(^6\) Pa would equal the pressure in a bubble of radius 150 um. The pressure inside a clathrate cage of radius 1 nm would be 1.4 \times 10^{11} Pa. It seems impossible therefore that a shock wave of 10\(^6\) Pa could distort this enough to remove the contents.

The Del Giudice hypothesis for potentized water proposes on the basis of quantum field theory, that domains of coherent water molecules can be formed due to the coupling of coherent naturally occurring resonance radiation (Section 1.6). It is proposed that the 50 cm\(^{-1}\) resonance would give rise to domains of coherence which
are 300 um in size. A domain this size would contain about $10^{17}$ molecules of water. The size of random fluctuations in this number that would not break coherence is $\sqrt{10^{17}} = 3 \times 10^8$. An incident electromagnetic wave that would not break the coherence, and which did not interact with a single water molecule in the usual manner, could interact coherently with a massive $3 \times 10^8$ water molecules and result in a slow wave with a velocity reduced by $3 \times 10^8$, that is to the order of 1m/s. The fundamental frequency of 1.5THz (corresponding to 50 cm$^{-1}$) would then be reduced to 5kHz. Del Giudice in his later work considers that a resonance at about 100 nm (12.04 eV) in the ultra-violet is more fundamental and that this gives domains of coherence in water that are 75 nm in size, although he still allows for the possibility of larger domains. In all experiments described in this thesis, there was no evidence of a persistent 5kHz. Furthermore, if the 5kHz resonance in water was fundamental, Smith C. would have found hypersensitive patients who reacted to it but this was not described.

The experimental results obtained in the work described in this thesis do not support any of the hypothesis described in Section 1.3-1.6. The few indications of the presence of coherent signals in water failed to pass the test of repeatability and were only observed on a few occasions. The fact that they were observed at all, raises the questions as to how they can
happen, and what physical processes are involved. It must now be assumed that certain critical conditions necessary for their appearance remain to be discovered and that these were only satisfied by chance so far. The statistical analysis of the frequency spectrum of magnetically potentized water suggests that any coherent domain are not coupled through a periodic electromagnetic field so, the mechanism of "water memory" remains to be understood.

The work in this thesis attempts to repeat experiments conducted by Ludwig (1988). However, Ludwig did not publish details of his experimental procedures, and therefore the experimental work conducted in this thesis could only be based on the limited information given by Ludwig. For example he gave no details on the design and spacing of his electrodes, nor whether he obtained signals when the electrodes were first in conduct with the remedy or some time afterwards. Although the experiments conducted by the author have failed to replicate Ludwig's findings or conclusions, it is possible that this is because the exact experimental procedures curried out by Ludwig were not able to be duplicated.
CONCLUSION

The work described in this thesis started with a review of the relevant publications on water "memory" effects. The changes in physical properties of potentized water have been discussed, with special reference to the possible molecular structure of "treated" water. From this review it was shown that a number of physical and biochemical properties are reported to change as a result of potentization. In addition, a specific property which could lead to an experiment which could describe the potentized water in terms of variation in one of its physical properties could not be established.

Based on Ludwig's protocol for detecting coherent electrical signals from homoeopathic remedies, together with the experimental fact that water potentizes in a magnetic field, it was considered essential to begin with a controlled electromagnetic environment. Thus, an electromagnetic shield of high performance was designed, built and tested. The shielding effectiveness of both electric and magnetic fields were calculated. Such calculations do not seem to have been done for this sort of enclosure, nor was there any previous theoretical treatment concerning the shielding effectiveness of such enclosures. Instrumentation for testing the shielding effectiveness was designed and constructed. For the testing of the shielding effectiveness of the enclosures constructed only general guide lines were available in the literature. A large number of approximations were made both in these calculations and in reaching a compromise design to fit the space and environment available. The objective to finish up with a high performance enclosure capable of providing an interference free environment and internal magnetic fields below the level at which water will potentized was achieved.
For detecting weak electrical signals from potentized water, a low noise amplifier was designed and built with carefully selected low noise components in order to achieve the best possible low noise characteristics. Its measured performance gives a noise voltage equal to that of a 47 Ω resistor, thus the sensitivity of the overall system was limited by the noise produced at the electrode-electrolyte interface and that of the electrolyte. This was found to be depending mainly on the salinity of water and the spacing between the electrodes. From this a number of mineral waters available in the market have been characterized in terms of their noise level.

There are a number of theories published on possible mechanisms for the storage of bio-information within the molecular structure of water but only the most acceptable models are considered in regard to the properties of water and the versatility of water "memory" given here. There are grounds to support the idea of water molecular models proposed for potentized water. The hypothesis of Barnard and Stephenson on potentized water are given credibility through the known molecular structure of ice, and that ice from potentized water is equally effective. Del Giudice derived a theory for water as an electric dipole laser through quantum field theory which led him to the concept of domains of coherence in water. Vithoulkas came to similar conclusion with his idea of hydrophobic cluster formation in water.

From these hypothesis three main classes of experiments were devised.

a) The acoustic absorption of water at low frequencies, which tests for any large number of cluster or ordered molecular structure present in potentized water. This is based on the Barnard, Vithoulkas, Smith C., and Del Guidice hypotheses.
Experimental results showed broad resonance not at the imprinted frequency, nor any related frequencies and could not be interpreted. They were definitely not present in the "untreated" water.

b) The detection of electrical signals resulting from coherent domains or ionic defects on ordered structures have not been reliably obtained from water potentized with a known frequency, and there was no indication of coherent signals involved in homoeopathic remedies.

c) Their existence was best characterized through the statistical treatment of the noise frequency components of "treated water" acquired with a suitable data acquisition system attached to the output of the low noise amplifier. This was designed and constructed by the author after the amplifier measurements had failed to show definite repeatable evidence of single coherent frequencies in "treated water". The data obtained for the frequency spectra of noise from water and "treated" water showed large deviations in the mean and standard deviation for the "treated" water compared to the untreated control water. There was a simultaneous decrease in the standard deviation of the potentized water compared to the "control water". The standard deviation decreased approximately as the square root of the increase in the mean thus the Poisson distribution may describe these signals from potentized water.

Further work should be initiated with the statistical treatment of the noise frequency components of single frequency imprints in water with special reference to the role of the magnetic vector potential on enhancement of coherent signals. If the factors which can enhance the detection of the coherent signals in water are established a much better understanding of the mechanism involved should also be established leading to
reliable "read" and "write" frequencies in water. This will significantly contribute towards establishing the mechanism undergoing the clinical effects of potentized water and towards an understanding of water as an electronic "memory" device. A greater understanding of the effect of electromagnetic radiation on water structure would also lead to an explanation of the mechanisms by which electromagnetic radiation is thought to exert a carcinogenic effect.

"Life is so short and the craft so long to learn"

Hippocrates c460-c377 BC.
APPENDIX I

In this section the power spectrum of the noise measured from different mineral waters was obtained from the experimental setup outlined in Chapter 6.4, for a number of different mineral waters obtained from a local supermarket.

The different types of water tested are displayed in order of their noise level. Vittel water had the lowest noise level followed by Evian water which are shown in Figure 1, Buxton water and Volvic water are shown in Figure 2 which was found to have the highest noise level. The noise in the power spectrum was found to be related to the salt contents of the waters, as was shown on their respective labels, and summarized on chart below.

<table>
<thead>
<tr>
<th>in mg/l</th>
<th>Volvic</th>
<th>Evian</th>
<th>Vittel</th>
<th>Buxton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>9.9</td>
<td>78</td>
<td>91</td>
<td>55</td>
</tr>
<tr>
<td>Sodium</td>
<td>9.4</td>
<td>5</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.7</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>84</td>
<td>116</td>
<td>80</td>
</tr>
</tbody>
</table>
Figure 1. Top trace shows the power spectrum of VITEL water. Bottom trace shows the power spectrum of EVIAN water.
Figure 2. Top trace shows the power spectrum of BUXTON water.
Bottom trace shows the power spectrum of VOLVIC water.
A data acquisition system was built for investigating the statistical properties of noise involved in "treated water". The Onnosoki FFT analyzer used had the facility of data and file recording and writing onto a floppy disk, but the data were recorded in a format suitable for the spectrum analyzer only, and any further analysis of the data in that format was not possible.

The system built by the writer consists of three parts a) the data acquisition system b) the antialiasing filters and c) the software for the data analysis.

**DATA ACQUISITION SYSTEM**

The main advantage of acquiring data in a personal computer (PC) in text format is that one can further analyze it on any other compatible software.

There are three main ways to acquire digital data into a PC.

a) Data acquisition through the expansion bus; this usually requires complex digital control and buffering circuitry, the availability of a suitable expansion slot and an expensive printed circuit board. However, high speed data transfers can be achieved as compared to the following two methods. Typical values of this data rate are computer power and software dependant.

b) Digital data may also be acquired by a PC via the asynchronous serial port (RS232). Using this method, the speed of acquiring data is decreased by the start and stop bits required for this mode of communication, and suitable serial interfacing
hardware is complicated especially when analogue data are first converted to digital and then to RS232 formats.

c) Finally digital data may be acquired via the parallel port or printer port or Centronics port of a PC.

The data on a Centronics port can be read or written in a synchronous manner usually 8 bits at a time. However, with suitable software one can read one bit at a time, or write one bit at a time to any one of the 8 pins available for the data transfer. With the special software and hardware developed by the writer was based on Davis (1994), the data are read serially that is one bit at the time but also synchronously. This is very useful in the case were a serial output analogue to digital converter (A/D) is used. With the software built, pin 14 on a the standard 25 pin Centronic port is used for chip selecting the A/D converter, and pin 1 provides the synchronous pulse required for the communication while pin 11 reads data from the A/D. The A/d used was type TLC549. The circuit diagram of the data acquisition system is shown in Figure 1. The voltage is stabilized at 5 V with the voltage reference device LM334 which also provides a reference voltage to the A/D. The data are stored on the floppy drive of the PC in "text" format with values from 0 to 256 corresponding to 0 and 2.5V of input voltage. The acquired data are stored in batches of 256 with a small interval taken up by the PC to actually write the data on to the floppy disk. The time required for that is PC power dependent and for a Tandy PC AT this takes about 2 seconds. The software used for analyzing the data is the "Easy Plot" which has the capability of performing the Fourier transform and statistical analysis of the data.

Suitable low frequency antialiasing filters were built by the author in previous work for the same reason Tsouris (1991). The sampling rate for a PC TANDY was 12 kHz so by Nyquist signals
up to 6 kHz could be investigated. However in order to have adequate resolution at least 10 samples are required to define reasonably well a sinewave. This effectively makes the system suitable for signals up to 1 KHz.

The antialiasing filter chosen was an inverse Chebichev type and the design was based on Van Valkenburg (1982). The inverse Chebyshev filter is similar to the Butterworth in that it is maximal flat in the passband, but unlike the latter it has attenuation poles in the stopband. Thus with respect to the stopband, it is similar to the Chebyshev-Gauer filter, and like the latter it is in the transfer function finite zeros. Because of these finite zeros Chebyshev has sharper transition region than the corresponding Butterworth filter but small ripple in the pass-band like the latter. The filter was designed to have a cut-off frequency at 4.3 kHz and was measured to have a roll-off 62 dB/octave. The circuit diagram of the filter is shown Figure 2.
Figure 1. Circuit diagram of the data logger.
Figure 2. The circuit diagram of the Inverse-Chebyshev filter.
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