b) Induce voltages in the lead that damage the pulse generator;

c) Induce voltages in the lead that the pacemaker confuses with the intrinsic heart signal and turn off the pulse generator.

Additionally implantable pulse generators incorporate reed switches which are used for controlling the battery charge and may be activated by strong magnetics fields.

The safety of implantable pacemakers and their protection against EMI (Electro Magnetic Interference) is the subject of the CENELEC European Standard 56001.

A draft amendment prepared by the Technical Committee 62 [1] suggests both the maximum ratings of interference and the measurement methods to which pacemakers should comply.

Surely clauses a) and b) do not concern the GSM system because the power of a direct radiation excited in the lead which can damage the heart or the pulse generator is very much higher than the power of the GSM fixed or mobile equipments. Moreover the transmission frequencies of the GSM system are so high that the by-pass capacitor which protects the pacemaker input filtrates enough the residual components. For instance it has been verified that AM radio broadcast transmissions using very high power (kilowatts or megawatts) can introduce a strong hazard.

Instead, clause c) has needed some investigations because an interfering signal with low frequency components approximating the heart beat could cause potential hazards even if their power is relatively low.

In case of GSM signals, while the normal burst transmission has a repetition rate of 216 Hz and risks cannot arise (consider that a 50 Hz component is already strongly filtered by the post-detector filter of the pacemaker detector input), the particular case of DTX (Discontinuous Transmission) mode had to be carefully investigated.

In fact DTX mode has signal components at frequencies much lower than in the case of normal GSM transmissions (see fig. 2): there is a sub-component with a repetition rate of 2.08 Hz, which corresponds to the transmission of the 8 timeslots of the SID (Silence Descriptor) message block frame and another low frequency component represented by the SACCH repetition rate (8.33 Hz). The amplitude and duty cycle (one timeslot out of 26) of this component are much lower than those of the previous one. Since electrical signals with a periodicity below 6-8 Hz inhibit the pulse generator while interfering signals with a periodicity above 6-8 Hz will revert the pacemaker operation into the so called asynchronous mode at the basic programmed rate, it was fundamental importance to identify possible danger thresholds.

In fact, if the power excited by these signals in an active pacemaker were high enough, the pulse generator could be turned off and the person could have a heart failure.

3 - Experimental Tests

Compatibility tests have been conducted both with unipolar and bipolar pacemakers manufactured by SORIN using the test set-up shown in fig. 3.

An arbitrary waveform generator jointly with an RF generator simulated the 900 MHz DTX transmission. The signal was amplified by a power amplifier.

Pacemakers were placed in a phantom, an imitation of the human body filled with a physiological solution (water and NaCl whose concentration corresponded to a specific conductivity of 0.5 S/m at 20°C room temperature) according to the standard values.

The phantom was a Plexiglas cylinder 1.7 m tall, with a diameter of 0.3 m. The pacing lead was placed in a loop similar to the one really done in the human chest and his distance from the plexiglas wall was not larger than 1 cm. An oscilloscope connected to two steel plates plunged into the solution was used to detect the regular operation of the generators.

Experiments were conducted in a controlled (anechoic) environment with the aim of measuring the field strength next to the phantom chest by an isotropic detector avoiding any unwanted component.

The measurement results show that no risk of hazards exists against pacemakers from GSM equipment.

In fact it has been verified that it is necessary an electric field of at least 40 V/m (corresponding to 8 W transmit peak power of a GSM equipment at 0.5 m distance) for inhibiting an unipolar pacemaker when the device is leaved in the air with the pacing lead loaded with a 500 ohm resistor simulating the tissue interface.

On the other hand, when the device was put into the physiological solution, it was not possible to inhibit his regular operation even with electric fields of 200 V/m (corresponding to 208 W transmit peak power at 0.5 m distance).

For bipolar pacemakers the results are even more reassuring: with the device in the open air the electrical field could inhibit the pulse generator only if it was above 75 V/m (corresponding to a transmit peak power of 28 W at 0.5 m distance). Obviously no inhibitions have been detected with the pacemaker plunged into the solution.

4 - Conclusions

DTX transmissions of a GSM equipment produce waveforms which could inhibit cardiac stimulators but formal experiments carried out with modern unipolar and bipolar pacemakers manufactured by SORIN have demonstrated that no real hazard exists.

References

[1] "Safety of implantable cardiac pacemakers", Draft CENELEC pr EN 50 061 (1989)

[2] "Immunity to disturbance of cardiac pacemakers in RF fields of powerful radio transmitters", Institut fur Runfunktechnik GMBH, Munchen, 1987.

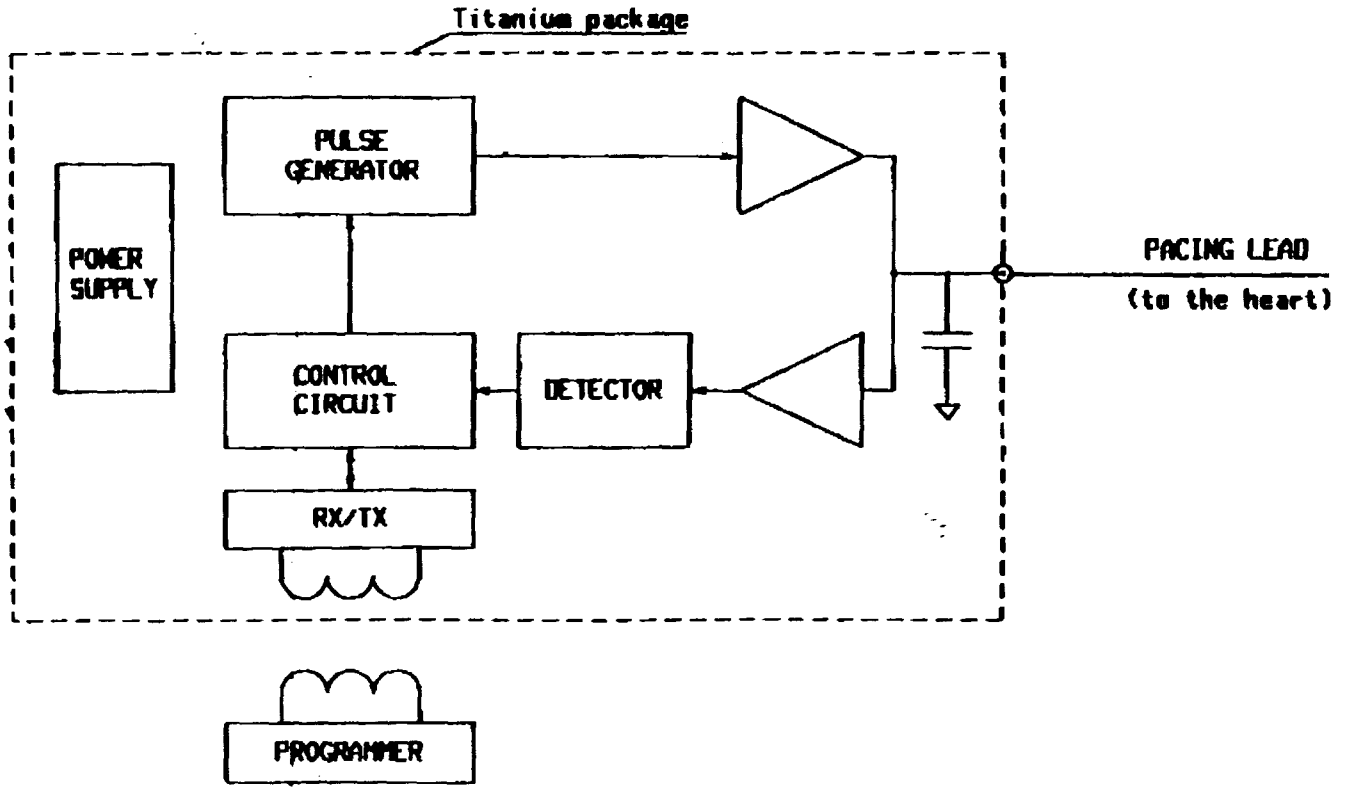

Fig. 1 Schematic diagram of a cardiac pacemaker

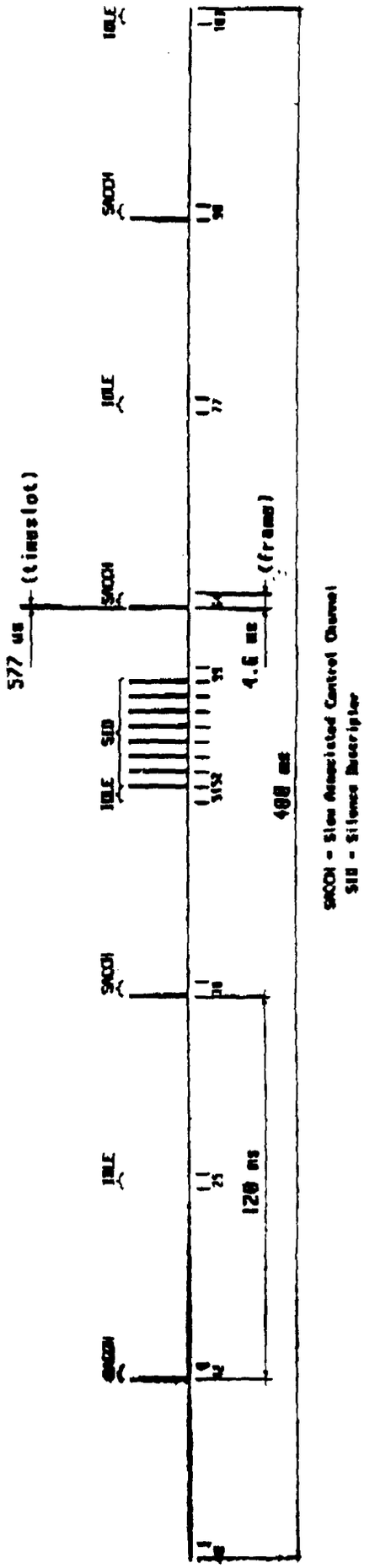

Fig. 2 GSM System Discontinuous Transmission (DTX)

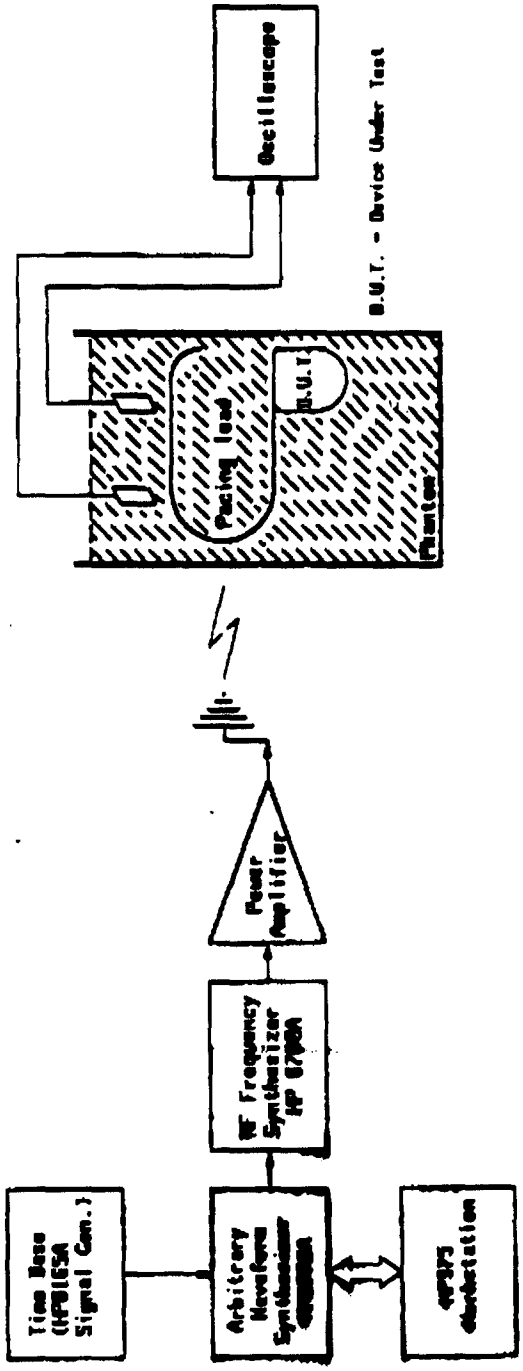

Fig. 3 Block Diagram of the experimental setup

Annex E: Summary document on GSM-TDMA interference

Summary Document
On
GSM-TDMA INTERFERENCE

PROJECT: 60
Support to R2/MTS2

July 1991

RTL File XJ201

Project Manager F Mellish, I.Eng. MIEIE

Project Technicians

Approved by .....

L Williams, I.Eng. FIEIE
Head of Research and Development

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1. Summary of Requirement.

2. Summary of Findings.

3. Immunity Data.

3.1 Sources of Data
3.2 Normalisation of Data.
3.3 Analysis of Data.

4. Observations.

5. Conclusions.

1. Summary of Requirement.

In the course of a meeting to discuss the potential interference [1] problems associated with the introduction of GSM and other transmission systems employing TDMA techniques, Mr Williams of the Radio Technology Laboratory was tasked with producing a summary document covering all of the work carried out to date.

The minutes of that meeting are reproduced in annex 5, it should be noted that the chairman stated that the summary report should aim to concern itself with the direct breakthrough problem only, and <u>not</u> the TV image problem which may affect the UK only.

[1] Interference to TV, radio, audio and information technology equipment, including personal stereo equipment and hearing aids.

2. Summary of Findings.

2.1 Domestic Equipments.

Television receivers and portable radios/cassette players etc. proved to be the most susceptible domestic equipments with mean immunities of 4.0 and 5.6 V/m respectively. Ignoring all receiver spurious responses, these equipments would only suffer interference from a 20 W GSM mobile at distances of less than about 8 metres (worse case assuming 100% efficiency and free space path loss).

This means that in practice, due to building attenuation etc., interference will not occur unless the transmitter and victim equipment are very close, and within the same room.

It can therefore be concluded that GSM interference is unlikely to cause any serious problems to domestic equipment, being used in a domestic environment.

2.2 Hearing Aids.

Hearing aids also proved fairly susceptible, having a mean immunity of 4.1 V/m. Interference to hearing aids (and portable cassette players etc.) outside the domestic environment is likely to prove more problematic since the interfering GSM transmission is unlikely to be under the control of the user of the victim equipment.

Work conducted by the RTL and Racal Research Ltd. suggests that the immunity of small behind the ear hearing aids can be improved at reasonable cost (by about 10 dB) by applying conductive paint to the inside of the hearing aids plastic case. This would reduce the interfering range of a 5 W portable GSM transceiver to about 0.5 metres which is considered acceptable.

It can therefore be concluded that users of current hearing aid equipment are likely to experience some interference from GSM mobiles in close proximity. It is difficult to predict whether this will be a serious problem, but since the immunity of hearing aids can be improved at reasonable cost, and bearing in mind that the use of personal communications equipment will increase, it would be seem prudent for hearing aid manufacturers to investigate this course of action.

It is unlikely that the users of hearing aid equipment will be able to use any TDMA communications systems themselves (even if the low cost improvements described have been incorporated).

2.3 Higher Frequency Systems, DECT, DCS1800 etc.

The hearing aids tested proved more susceptible to 1900 MHz than 900 MHz (mean immunity 7 dB worse). This has obvious implications regarding the introduction of DECT etc.

3. Immunity Data.

3.1 Sources of Data.

Reports from the following laboratories were analysed to produce this summary document;

Radio Technology Laboratory Reports KJ109, KJ132, KJ132a, KJ181 Part1, KJ181 Part2.

British Telecom Research Laboratories Report RT4123

Netherlands PTT (hoofddirectie telecommunicatie en post) Report

Radio Frequency Investigations Report RFI\TR2\2294

3.2 Normalisation of Data.

The above laboratories presented their findings in a variety of forms. In producing this summary report it was necessary to unify the various abstract results and findings, by calculation and extrapolation, to a common form - the field intensity at which the impairment was on the limit of acceptability.

CCIR grade 3.5 impairment was considered an appropriate limit of acceptability for GSM interference since it falls halfway between the impairment that is considered acceptable, by the CCIR, for continuous interference (CCIR grade 4), and that which is only considered acceptable for a very small percentage of the time (CCIR grade 3).

The approximate field intensities that would result in CCIR grade 3 or 4 impairments can be obtained by adding or subtracting 5 dB audio impairment respectively (since a 1 dB change in the field intensity results in approximately a 2 dB change in the audio impairment (square law), multiplying or dividing the grade 3.5 field intensity by 1.33 will produce the approximate grade 3 and 4 field intensities respectively).

A description of the impairment associated with each of the standard CCIR impairment grades is given in Annex 1.

3.3 Analysis of the Data.

The original laboratories data and its conversion to field intensity for grade 3.5 impairment is given in Annex 2.

The Mean and Standard Deviation of the extrapolated data is given in Annex 3, and Summarised in Annex 4.

4. Observations.

4.1 Earlier work at the RTL has shown that the magnitude of AM or pulse[2] interference is related to the peak envelope power of the transmission. i.e. A victim equipment demonstrating immunity to 3 V/m (carrier) with 1kHz, 80% amplitude modulation, is also demonstrating immunity to 5.4 V/m peak i.e. a TDMA immunity of 5.4 V/m. This is supported by the recent tests conducted on hearing aids by RFI.

[2] 1:24< duty cycle <24:1

4.2 The recent tests conducted by RFI shows that the majority of the hearing aids tested (the smaller ones) were more susceptible at 1900 MHz than at 900 MHz (the mean immunity was 7 dB worse). This finding has obvious implications regarding the introduction of DECT etc., and is supported by some (limited) earlier work conducted by the RTL (KJ132a).

4.3 *Intentionally blank for reports disseminated outside the Agency.*

5. Conclusions.

5.1 The extrapolated mean/median peak TDMA field intensities at which various equipments would suffer visible/audible, but not annoying interference (approximately CCIR grade 3.5) are listed below.

Type of Equipment	Field Intensity (V/m)
Hearing Aids	4.1
Television Receivers	4.0
Video Cassette Recorders	>13.9
Satellite Television Receivers	9.5
Tuners/amplifiers	>8.3
Cassette Decks	>2.9
CD Players	>13.9
Portable Radios & Cassette Players etc.	5.6
Telephones	>7.6
Computers	>8.5
Computers (Home/Games)	>13.5
General Electrical/Electronic Equipment.	>7.8

From the above generalisation it can be seen that the most susceptible equipments are hearing aids, television receivers, cassette decks and portable radios/cassette players etc. Ignoring all receiver spurious responses [4], these would only suffer interference from a 20 W mobile at distances of less than about 8 metres (worse case assuming 100% efficiency and free space path loss). This means that in practice, due to building attenuation etc., interference will not occur unless the transmitter and victim equipment are very close, and within the same room.

It can therefore be concluded that GSM interference is unlikely to cause any serious problems to domestic equipment, being used in a domestic environment. Interference to hearing aids and portable cassette players etc. being used outside the domestic environment is more likely. Earlier work conducted by the RTL and Racal Research Ltd. suggests that the immunity of small behind the ear hearing aids can be improved at reasonable cost (by about 10 dB) by applying conductive paint to the inside of the hearing aids plastic case. This would reduce the interfering range of a 5 W portable GSM to about 0.5 metres which is considered acceptable.

[4] Although it was requested that this summary report should aim to concern itself with the direct breakthrough problem only, and not the TV image problem which may affect the UK only, the following background information is included for completeness.

The image (spurious) response of television receivers is potentially quite problematic because, for some of the higher Band V channels, this response falls within the bands allocated to TACS and GSM. However, interference via this mechanism is no worse for GSM (or other TDMA systems) than it is for analogue systems e.g. TACS. As no cases of TV image interference from TACS have been recorded during several years of operation, major image interference problems from GSM are not anticipated.

5.2 The following pertinent information has been extracted from RFI's test report RFI\TR2\2494;

5.2.1 Generic Immunity Standards.
The draft generic immunity standard (prEN 50082-1) requires the EUT to be tested at 3 V/m from 27 MHz to 500 MHz, but since there is no requirement to modulate the field it is unlikely that any hearing aid equipment would fail this test.

The final version will almost certainly require that two further tests listed in the informative annex to be carried out:

1. Electromagnetic field at a severity level of 3 V/m 80% amplitude modulated with 1 kHz tone swept from 80 MHz to 1 GHz.

2. electromagnetic field at a severity level of 3 V/m pulse modulated with a 100 Hz square wave at a frequency of 1.89 GHz.

5.2.2 Field Strength Produced by Portable Transceivers.

Based on compliance with the generic standard RFI have calculated how closely the user of a piece of hearing aid equipment may approach a portable transceiver before the level of unwanted interference becomes unacceptable, and produced the following table;

System	Power (W)	Minimum Distance (m)
CT2	0.01	0.1
GSM	2.00	1.4
	5.00	2.2
	8.00	2.8
	20.00	4.5
DECT	0.25	0.5

RFI state that;

These figures only provide a rough guide as they make no allowance for the type of modulation employed or for the disturbance of the electromagnetic field caused by the person using the hearing aid.

and that;

The values calculated above would suggest that users of hearing aid equipment are likely to experience some interference from GSM mobiles in close proximity and that they will not be able to use any of the above systems themselves.

Annex F: Interference to hearing aids by the new digital mobile telephone system, Global System for Mobile (GSM) communications standard

Interference to Hearing Aids by the new Digital Mobile Telephone System, Global System for Mobile (GSM) Communications Standard

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TELECOM RESEARCH LABORATORIES

and

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NATIONAL ACOUSTIC LABORATORIES

NATIONAL ACOUSTIC LABORATORIES
a Division of AUSTRALIAN HEARING SERVICES
SYDNEY, 30 March, 1993.

ABSTRACT

This report gives the details of some measurements on the interference caused to hearing aids by mobile telephones using the new "Global System for Mobile" (GSM) Communications Standard. The widespread use of this system may cause considerable interference to users of hearing aids. It is not known at present if hearing aids can be designed to be completely immune from this interference. This report has been written to alert all hearing aid users and those concerned with the use of hearing aids to the possible disruption to the use of hearing aids that may be caused by the new GSM system.

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1 Introduction

The new mobile telephone system, using the "Global System for Mobile" (GSM) communications standard, is due for introduction in April this year. It uses digital technology and operates at radio frequencies (RF) in the 900 MHz region. The portable hand held and transportable telephones are capable of interfering with commonly used electronic equipment and can degrade the performance or even prevent the operation of hearing aids.

NAL was approached by Telecom Research Laboratories Electromagnetic Compatibility Section about the possibility of checking if the system interferes with hearing aids. Telecom was undertaking an investigation into interference caused by the digital telephones. As a result NAL and Telecom staff undertook a series of measurements designed to establish the nature and extent of interference to hearing aids.

The following is a report of these measurements, together with some recommendations.

2 Acknowledgments

Dr. Ken Joyner, Head of the Electromagnetic Compatibility Section, Telecom Research Laboratories, first approached NAL through Mr. Eric Burwood and visited NAL on 18th and 19th February, 1993 when it was established that interference may be a problem. Subsequently, measurements were carried out on 4th and 5th March 1993 to quantify the extent of the interference likely to be experienced by hearing aid users. Dr. Joyner and Mike Wood of Telecom Research Laboratories Electromagnetic Compatibility Section set up the equipment to generate the radio frequency field to simulate the telephone emissions and also provided Tables 3 and 4 of field strengths emitted by the GSM mobile telephones. Messrs. Eric Burwood, Derek Allison and Ross Le Strange of National Acoustic Laboratories carried out the hearing aid measurements.

3 Nature of Transmission from GSM Mobile Telephones

For the GSM system the radio spectrum available for mobile-to-base (i.e. mobile telephone) transmission is between 890 and 915 MHz, and for base-to-mobile it is 935 to 960 MHz. The modulation produces 0.6 ms bursts of RF energy from each telephone transmitter at a pulse rate of 217 Hz. A number of peak power levels and equipment configurations are available for GSM mobile telephones for use within Australia. These include a 2 watt hand held unit and an 8 watt transportable unit. When due account is taken of the pulsed nature of the transmissions, the corresponding average power levels are 0.25 watt and 1 watt respectively.

The peak RF field strengths close to the antenna of the mobile telephone can be quite high. At 10 cm from an 8W transportable unit a peak RF field of 70-80 V/m has been measured.

The GSM system is a pulsed system with a higher peak power than the present analog mobile telephone system. This makes the GSM

system much more likely to cause interference into electronic equipment which is apparently not affected by analog RF fields. Obviously the potential for interference depends on the number of GSM mobile telephones in use in the community and this is unlikely to be very high in the next few years.

4 Interference to Hearing Aids

Interference to a hearing aid is considerable, the amount depending on the details of its design. Considerable concern is felt by the European Hearing Instrument Manufacturers Association as the new system is being implemented in all European countries. The Australian Telecommunications Authority, Austel is embarking on an investigation into "emerging technologies for the delivery of wireless personal communications".

The interference from one transmitter is heard in the hearing aid as a constant, distinctive buzzing sound while the telephone is transmitting nearby. Figure 1 shows a typical frequency spectrum of the output of a hearing aid with interference, which occurs across the useable range from 200 to over 5000 Hz.

Hearing aids from all manufacturers will be similarly prone to this interference.

5 Description of Measurements - Sensitivity of the Hearing Aids to the Interfering RF Signal

a <u>Aim</u>: To measure how the effect of the interference varies with the peak RF field strength, so that useful predictions could be made about the effect on hearing aids in proximity to these telephone transmitters. This was done by:-

i Measuring the output of the aids subjected to varying RF field strengths, and

ii Subjectively comparing the interfering output with a sound of known intensity.

b <u>Method</u>:

i The hearing aids were placed in a known variable RF field generated by the system provided by Telecom shown in Figure 2. The sound output of the hearing aid was measured in a 2 cc coupler with a B&K 2120 Frequency Analyser set for wide band with a 100 Hz high pass filter to guard against low frequency ambient noise, refer to Figure 3.

ii The noise floor of each aid was measured with the microphone blocked to ambient noise. The hearing aid output was then measured under a suitable range of field strengths, including that which produced an output 10 dB above the noise floor.

c <u>Precautions</u>:

i The measuring microphone and acoustic 2 cc coupler are large metallic objects which alter the field strength around the hearing aids. In order to obtain reasonably

accurate field strength at the aid, the 2 cc coupler and microphone were moved away from the vicinity of the aid. A 460 mm length of 2 mm diameter Tygon tubing was necessary to couple the aids to the 2cc coupler. This changed the acoustic frequency response of the aid, an example of which is shown in Figure 4. This change of response does not invalidate the measurements for the purpose of this investigation, since the bandwidth was not reduced significantly. The peak RF field strengths were measured using the apparatus shown in Figure 2. The output of the generator was varied with its attenuator in order to adjust the RF field incident on the hearing aid under test.

ii On rotating the aids in the RF field the received interference changed. However, for the purpose of this investigation, it was decided that the orientation which produced the most interference in the majority of aids would be used, since time was insufficient for a more extensive exploration and it is unlikely that significantly more useful information would have been obtained.

iii The frequency response of each aid was graphed with normal acoustic termination and also with the extra tubing using a NAL 8500 system whose calibration was checked with a B&K calibrator. This shows that the aids were operating correctly.

d <u>Tape Recordings</u>:

i The outputs of each aid was recorded with and without interference for subsequent subjective evaluation.

ii Recordings were made of the output of some of the hearing aids with test speech passages of known average SPL with and without interference to ascertain what may be deemed a suitable threshold for characterising the effect of interference. It was confirmed that a useful "annoyance" threshold is the RF field strength that causes an output 10 dB above the noise floor of the hearing aid, i.e. the output without interference and when the microphone was blocked to ambient sound. Increasing levels of interference rapidly increases the level of discomfort, e.g. when the interference was increased to 20 dB above the noise floor, the effect became unacceptable, even though the accompanying speech was still intelligible.

iii It is intended to prepare a cassette tape recording with samples of a hearing aid output with and without interference to speech.

6 Interpretation of the Results

a Interference Threshold: Table 1 shows the threshold values obtained with the hearing aids issued by AHS. Interference when the telecoil is used is slightly different to that with the microphone.

b Range of Interference: Table 2 gives an approximate indication of the relative distances at which the 10 dB threshold is reached from a 2 watt GSM hand-held mobile telephone, and from an 8 watt GSM Transportable mobile telephone. These are estimated from the hearing aid thresholds in Table 1, and by extrapolating from the peak RF field strength measurements over grass in Tables 3 and 4. As indicated in Tables 3 and 4, significant variations occur in field strengths depending on the immediate environment, however the estimated values rank the aids correctly and give a realistic indication of the range where interference will occur.

c Conditions under which Interference Occurs:

i The telephones interfere with all the hearing aids tested. A user of one of these hearing aids will not be able to use these telephones, and a hearing aid will often become useless or cause the wearer discomfort close to a telephone when it is being used. This situation is representative of currently available hearing aids. It will be noticed that the IT312 has the least interference. An explanation is given below.

ii Behind-the-Ear hearing aids experience more interference than In-the-Ear aids.

iii Hearing aids such as the VHK are likely to be unusable even several metres away from either the hand-held or the transportable telephones.

7 Interfering Mechanism

a From the experimental work we can say that the interference occurs at the most sensitive part of the hearing aid amplifier, where the RF field induces signals in the wires connected to the microphone or the telecoil and detected (rectified) by the transistor input, and possibly by the output of the microphone which has a simple buffer amplifier. This mechanism applies in high gain audio amplifiers such a those used in public address systems that are subject to AM radio and television transmissions. These are normally shielded from this interference and the input shorted by a small capacitor to eliminate the problem.

b The higher peak pulses of RF power radiated and the close proximity to the hearing aids where they will normally be used, combine to make this interference more severe than the above cases.

c Sometimes a small capacitor is used shunting the amplifier input to prevent RF signals being detected and heard by the wearer. The Calaid Sonata has a small capacitor, but is not

close to either the amplifier chip or the microphone. The Serenade, VLK and VHK/MK do not. This explains the lower threshold RF field strengths of the V aids. The new IT312 has much shorter microphone leads than the previous ITE hearing aids Sonata and Serenade, since the microphone is solidly mounted next to the amplifier board. The lower sensitivity to interference is consistent with the above mechanism.

8 **Remedies**

a <u>Possible Approaches</u>

i Filtering: The shunt capacitor is a simple filter. It should be placed physically very near the amplifier integrated circuit chip with very short wires. It may also be necessary to place one across the microphone output at the microphone. The capacitors are restricted by their affect on the circuit operation as well as taking up valuable space. By using a small ferrite inductor in series with the microphone leads in conjunction with the shunt capacitor, it may be possible to eliminate interference.

ii Shielding: Complete shielding of the whole hearing aid with a conductive sheath will eliminate the interference, but is likely to be impractical. Suitable methods include thin metallic coating on the inside of the case parts, impregnation of the plastic with fine conducting particles and using a "metallic" paint. It may reduce the sensitivity of a telecoil if fitted. It is likely to be impossible to completely shield the aid, and connecting leads for audio input and induction pickup coil (telecoil) that are not shielded would present problems.

iii Feasibility: It is not known now if these or other remedies will work and to what extent they may work.

iv Restricting the use of the new GSM mobile telephones will prevent interference, but would probably make the GSM system useless.

b <u>Existing Hearing Aids</u>: Changes to the large number of existing hearing aids has the following problems:

i It may be logistically difficult, if not impractical.

ii Feasible modifications are likely to be of minimal effectiveness because of the difficulty in applying effective remedial treatments to an existing product.

iii Modifications to existing aids may be very expensive.

c <u>New Hearing Aids</u>: If effective means to prevent interference are developed, they could be designed into new hearing aids.

9 **Conclusion**

a It is likely that hearing aid users will be inconvenienced to some extent very soon after the new telephones are

introduced.

b Widespread use of the new GSM mobile telephones may make existing hearing aids useless for much of the time.

c Unless there is a realistic design remedy, new hearing aids will be affected, but possibly to a lesser extent, since partial remedies seem to be possible.

d Co-operative work to investigate effective design solutions is necessary, to establish if they can be developed.

e Monitoring the uptake of the GSM service and reports of interference to hearing aid users to gauge the extent of the problem in the short term and in the longer term undertake a co-operative programme to find practical and cost effective solutions.

10 Recommendation

a Make this problem known through:

i Austel,

ii Hearing Aid user Groups,

iii Hearing Aid manufacturers,

iv Relevant government departments,

b Initiate co-operative work to look for a suitable design solution,

c Keep the above mentioned bodies informed about the extent of the GSM system and inform GSM mobile telephone users about the interference that may be caused to hearing aid users.

11 References

a European Hearing Instrument Manufacturers Association, "Implications of GSM for the hearing handicapped", Bosstraat 135, B1780 Wemmel, Belgium, Tel 32-2-460 2284, Fac. 32-2-460 42449.

b AUSTEL, "Discussion Paper: Wireless Personal Communication Services", Mobile Equipment Standards Section, AUSTEL, P.O. Box 7443, St Kilda Road, Melbourne. Victoria, 3004

Table 1 RF Field Strength for Noticeable Interference to Hearing Aids (From measurements of AHS Hearing Aids)

Hearing Aid	Microphone Switched In			Telecoil Switched In		
	RF Field (Volts/metre)	Hearing Aid Output (dB SPL)	dB above Noise (no RF)	Threshold (Volts/metre)	Hearing Aid Output (dB SPL)	dB above Noise (no RF)
Behind-the-Ear Hearing Aids						
PPSCL	3.1	85.5	9.5	3.1	67.0	5.0
PPSC	2.8	94.5	9.5	4.9	87.0	10.0
VHK	0.7	89.5	9.5	0.4	77.0	12.0
VLA	1.6	62.0	12.0	2.0	59.0	12.0
PPCL4	3.1	85.0	11.0	3.1	74.5	9.5
In-the-Ear Hearing Aids						
JLFR Sonata	9.4	69.5	10.0			
S Serenade	4.9	66.0	10.5			
IT312 NAL-Phox	32.3	78.0	9.5			

Table 2 Threshold Distances for Noticeable Interference to Hearing Aids (Calculated from measured aid sensitivity and approximate field strengths near the telephones)

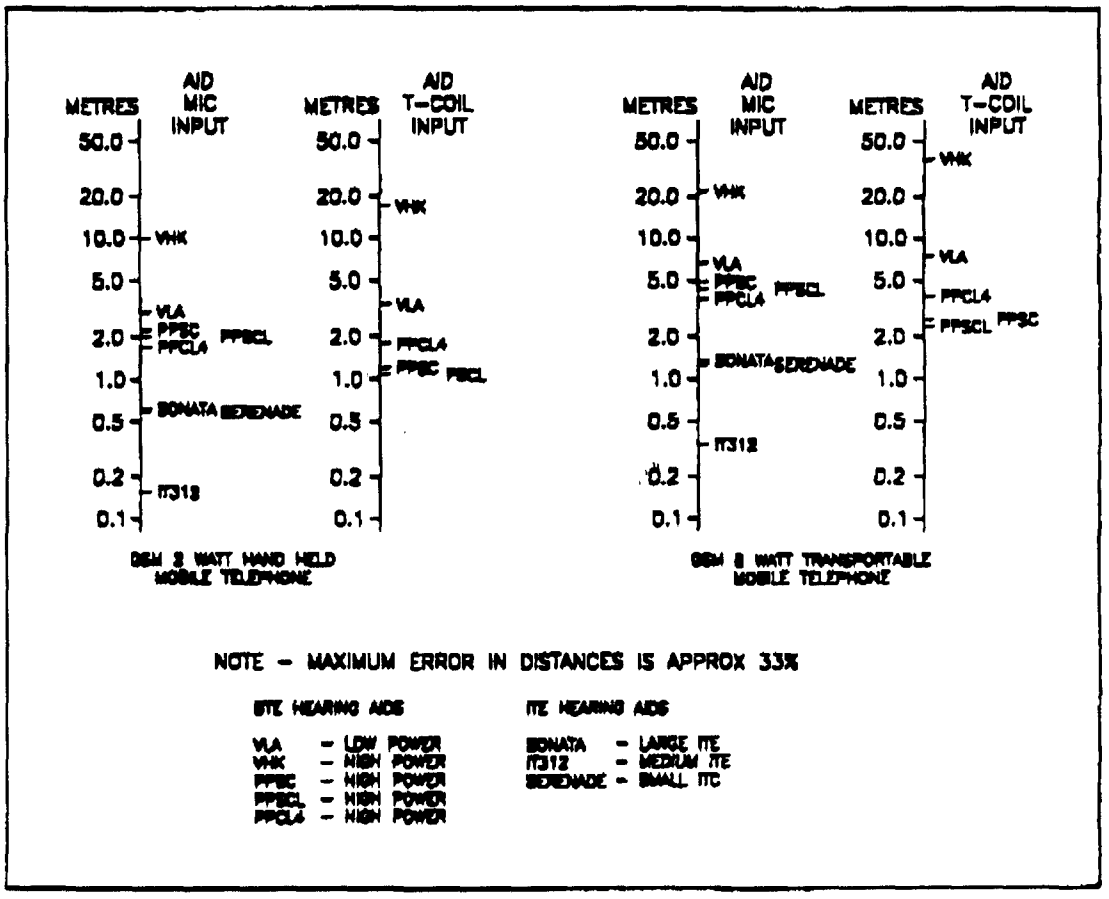

Table 3 Measured Field Strengths Near GSM 5 Watt Transportable Mobile Telephone, (Source Telecom Research Laboratories personal communication)

Distance (m)	TEST 1 - Outside Over Grass	TEST 2 - Inside Lab.	TEST 3 - Inside Lab. with Absorbers
	Field Strength (V/m)	Field Strength (V/m)	Field Strength (V/m)
0.1	81.8	76.3	
0.2	53.4	51.6	
0.3	34.9	36.9	
0.4	27.4	30.7	
0.5	21.8	23.3	25.0
1.0	12.0	12.0	12.4
1.5		10.1	
2.0	5.7	6.2	5.9
2.5		9.6	
3.0	4.0	7.5	4.1
3.5		3.4	
4.0	2.8	5.8	
4.5			
5.0	2.6		