Table 4 Measured Field Strengths Near GSM 2 Watt Hand-Held 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	41.9	38.7	
0.2	28.7	27.1	
0.25	24.1		
0.3	20.8	21.3	
0.4	15.0	16.3	
0.5	13.1	14.7	
1.0	5.5	7.1	6.2
1.5	3.4	6.4	
2.0	2.4	4.1	3.0
2.5	1.7	3.5	
3.0	1.7	4.3	4.3
3.5	1.1	4.0	
4.0	1.2	2.7	
5.0	0.8		

Figure 1 Sample Frequency Spectrum of a Hearing Aid Output with Interference

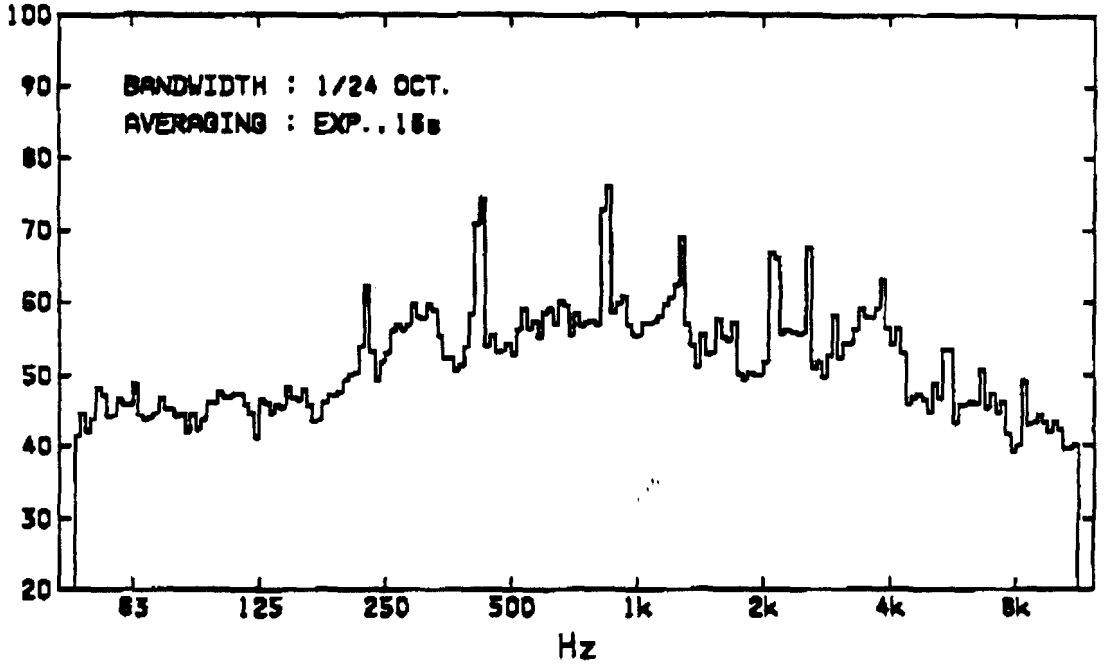


Figure 2 GSM Transmitter - Test Set-Up for Simulating Transmission

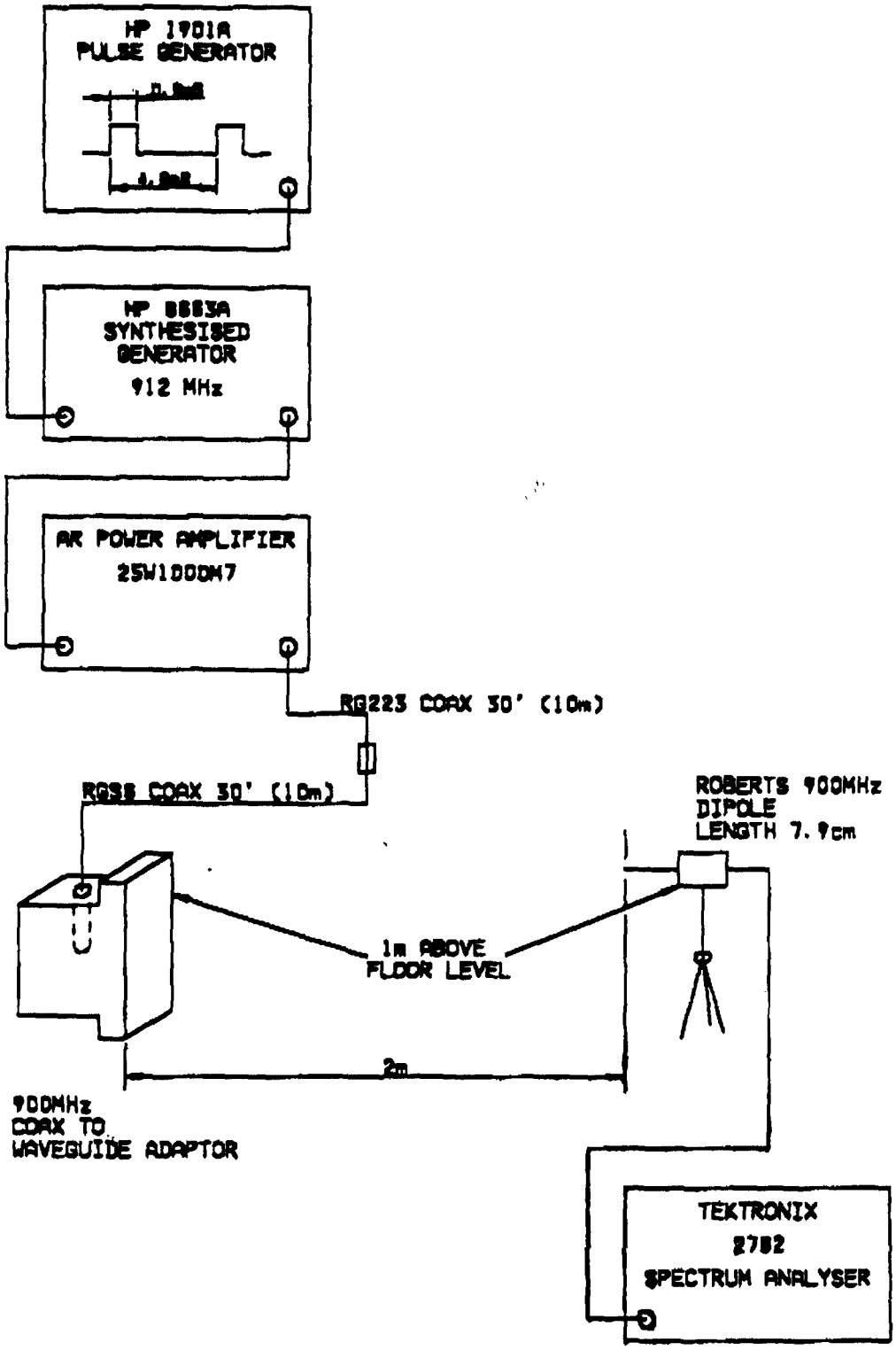


Figure 3 Hearing Aid Output with an Interfering Signal - Test Set-Up

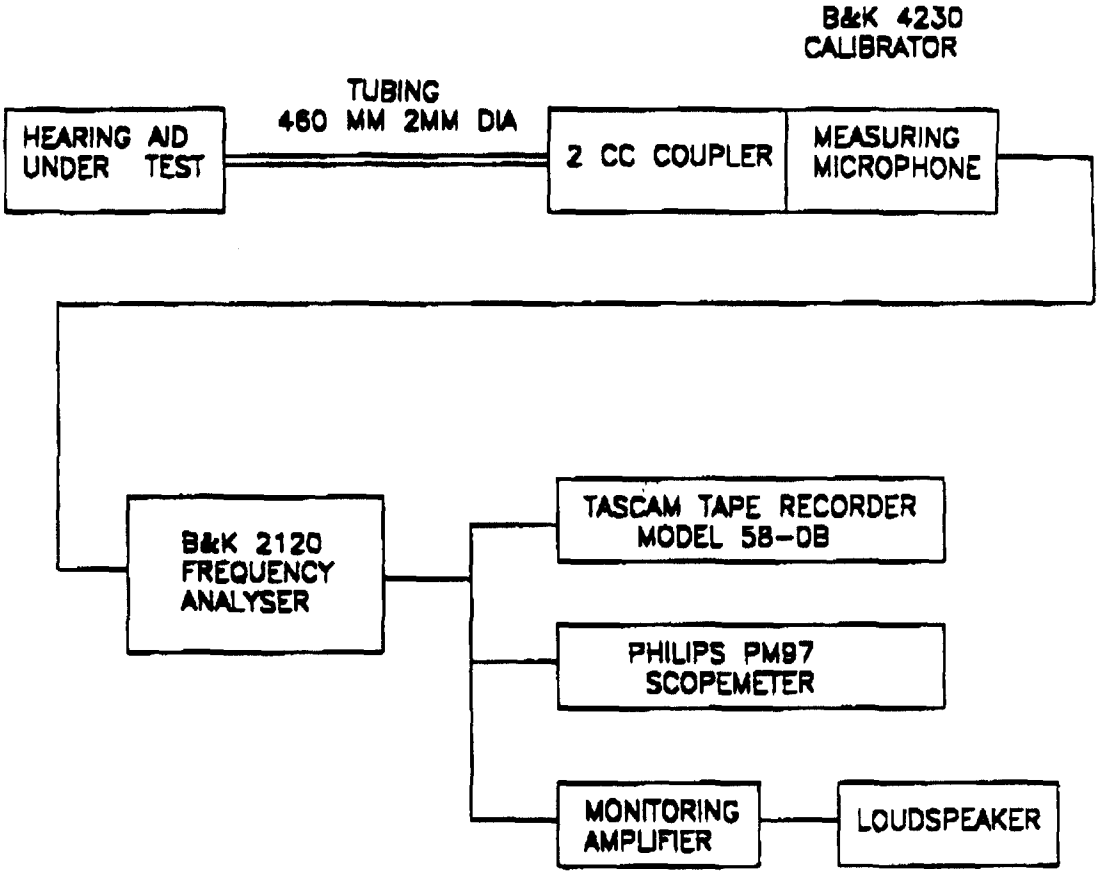
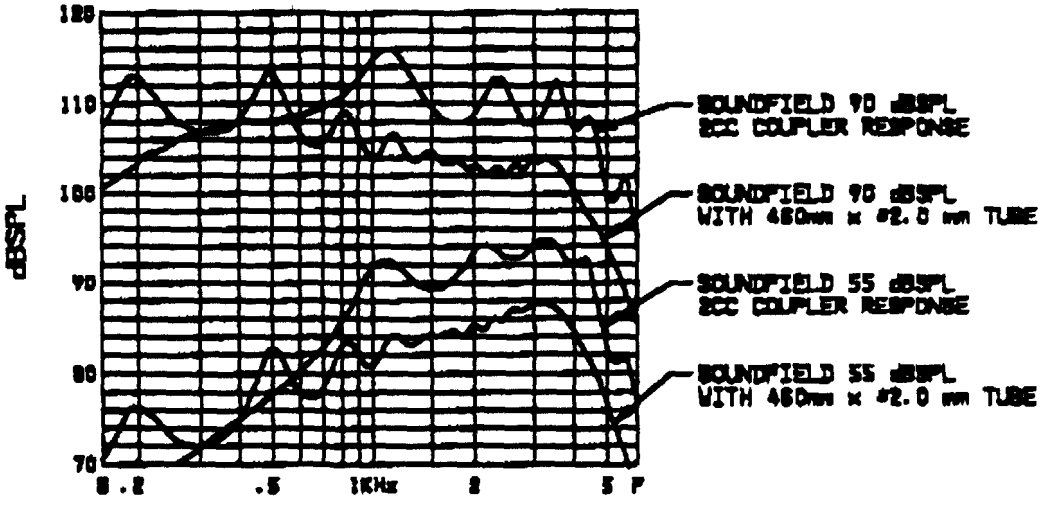


Figure 4 Sample Acoustic Frequency Response of Hearing Aid, with and without extended tube to 2cc coupler acoustic load.



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Annex G: Studies on interference from GSM terminals to the fixed network telephone equipment

This Annex includes four studies on the interference from GSM terminals to the fixed network telephone equipment. The studies are made by BTL, France Telecom, CSELT/SIP and Televerkets Forskningsinstitutt.

ETSI STC SMG2 No.5
9th - 12th March 1993
Brighton, UK

T.Doc 52/93 Rev 1

Source : BTL (UK)

Subject : EMC Considerations for fixed telephones in the UK

The table below shows the results of testing the immunity of various fixed telephones and PBX equipment (both analogue and digital) available in the UK. The testing was conducted at 3V/m and 10V/m using a simulated GSM test signal as the interference.

Mid-range Carrier-Frequency (MHz)	Modulation Type	Maximum Field-Strength (V/m)	R	E	S	U	L	T				
			1a	1b	1b	2	3	4a	4b	4c	5	6
866	CW	3	-	-	-	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-
"	AM	3	F	F	F	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	F	-	-
"	CT2	3	F	F	-	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	F	-	-
910	CW	3	-	-	-	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-
"	AM	3	F	F	F	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	F	-	-
"	CT2	3	-	-	F	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-
955	CW	3	-	-	-	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-
"	AM	3	F	F	F	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-
"	CT2	3	F	-	F	-	-	-	-	-	-	-
"	"	10	.	.	.	-	-	-	-	-	-	-

It can be seen that the vast majority of telephones and telephone equipment tested is not susceptible at even 10V/m. This field strength will be present at a distance of 1m from a Class 4 mobile. Therefore, although it is recognised that interference from GSM mobiles to fixed telephones is an issue, due to the UK immunity standard for fixed telephones, this is not considered a major problem in the UK.

Key :-

F Failed test
- Passed test
. Not tested

Where failure criteria was -40dBPa.

1 PBX with various terminal equipment
2 Payphone
3 MUX/DEMUX equipment
4 PBX with various terminal equipment
5 ISDN equipment
6 Line terminal equipment

Source: France Telecom

Subject: EMC considerations for fixed telephones in France

1.Introduction

Mobile GSM portable terminals have been identified in France as primary sources of interference to fixed telephones, electro acoustical devices and video displays.
As these were,at first,subjective results, testing of the immunity of various fixed telephones at close distance of a programmable GSM portable equipment was undertaken.

2.Experiments

A commercially available GSM unit was used for these tests,with a specific test SIM card.
This card transforms the terminal into a programmable unit with the possibility of chosing, the frequency (channel), the peak power and the sequence as well as many other parameters.

a) Frequency and fieldstrength:

The testing was conducted with field strength of 10 V/m and 3 V/m and 892 MHz frequency (by using two levels of power at the same distance of the terminal : one with a peak power of 8 Watts, the other with a peak power of about 2 Watts)

b) Performance criteria:

A very important point concerning the immunity of the telephone is the performance criteria.
For fixed telephones or acoustical devices, the main performance criteria is the fact that no noise should be listened to, caused by the GSM TDMA pulses (217 Hz and harmonics) occuring by audio rectification in the IC amplifiers,or non linear circuits of the electroacoustical devices.
In addition, for fixed telephones or PABXs , the audio rectification signal should not be sent in differential mode along the telephone line . It means that the correspondent should not listen to the demodulated signals occuring by the presence of GSM unit close to the telephone at the other end.
Two criteria are defined in France for the telephones concerning their immunity to the radiated or conducted interference.
First, the demodulated RF signal should not be sent on the telephone line with a power level higher than - 50 dBm in the audio transmission band , on a 600 Ohms impedance telephone line with a differential mode.
Second, no noise higher than 50 dBa weighted, should be listened in the earphone or in the audiotransducers
These parameters caracterize the performance criteria in the presence of RF fieldstrength and provide a generally accepted representation of the effect of good performance.Of course, no interruption of call , neither loss of stored numbers in memory should occur
The appendix show the test description and detailed results on these immunity tests.

3. Results and conclusion

With these parameters, it has been shown that :
Today, no telephone analog equipment or audio terminal can comply with a 10 V/m GSM type, fieldstrength
although EMC standards are mandatory in the country (1 or 3 V/m compliance is accepted with the old IEC 801-3 frequency limits 30 to 500 MHz plus AM modulation 1 kHz 80 %)
and ***3 on 8 fixed telephone equipment will comply with 3 V/m immunity requirements***.

It has to be mentioned that no loss of ongoing call, no dialing error , no loss of stored information occured, but the demodulated level was unacceptable .

Most of ETSI or CENELEC standards on EMC state only that no loss of ongoing call, no dialing error, no loss of stored data is the performance criteria , it is proved not sufficient to assess the electromagnetic compatibility.

Even , if it could be considered that if in the future, a specific standard from the CENELEC concerning telephone could include such immunity requirements, the GSM interference potential today is to be taken into account because there are millions of telephone equipment that are susceptible to close distance GSM emissions .

We consider that ***if a 8 W portable GSM terminal is used, the maximum distance of potential interference is typically about 10 meters*** maximum, and ***if a 2 Watts GSM terminal is used this distance is reduced to a maximum of 5 meters.***
In any case, we recommend that for non car-embarked GSM terminals, the radiated power should not be higher than 2 Watts peak power.

A contribution on this subject concerning a specific EMC standard of telephone and PABX equipment should be sent to CENELEC.

It is considered that interference from GSM terminals to fixed telephones and PABX is an issue through the European community, even if body worn audio and health electronic equipment is a major and much more important issue.

Appendix

1.Measurement of the immunity of fixed telephone equipment

In order to evaluate the immunity of electronic telephones to the emission of GSM terminals, two types of experiments were carried out:
First, a subjective test in a secretary office, the second is a formal immunity test in a semi-anechoic room .

1.1.Subjective test

In an ordinary secretary office, many different fixed telephones were installed .
We asked to various people present there to call with these telephones. An operator using a GSM portable 8 Watts peak terminal made a call at the same time.
As soon as the first phase of GSM search occured, all the telephones installed in the office were more or less highly disturbed by the presence of the GSM emission by superimposing a noise on the telephone audio band.
For the people who were the closer of the GSM terminal, the noise was not tolerable (1 m typically) and as the people were farther, the communication was made possible.

Typically, at a distance higher of 5 meters, the communication with the GSM did not disturb the other telephones.

1.2.Immunity test

The same GSM terminal was used in a semi anechoic Faraday cage and at a distance of 1 meters some fixed telephone terminals were set up with a test fixture in order to evaluate the demodulated audio noise provided by audio rectification on the earphone and on the telephone line .
To avoid any coupling with the field strength , the measurement equipment was put outside the semi-anechoic room.

The field strength was also monitored to make a correlation between the output power, the field strength and the demodulated output.

1.3.RESULTS

	GSM Output Power (W)	GSM Output Power (W)	GSM Output Power (W)	GSM Output Power (W)	GSM Output Power (W)	GSM Output Power (W)
	0 No emission	5	2	0 No emission	8	2
TELEPHONE	Demodulated audio level (DM) (dBm op/ 600)	Demodulated audio level (DM) (dBm op/600)	Demodulated audio level (DM) (dBm op/600)	Audio level (dBA)	Audio level (dBA)	Audio level (dBA)
T1	-73	-50	-48	41	71	62
T2	-73	-48	-48	35	70	60
T3	-73	-49	-52	43	79	69
T4	-73	-48	-53	35	75	64
T5	-73	-44	-57	35	90	67
T6	-69	-43	-53	36	65	64
T7	-74	-36	-48	37	80	70

The limits are -50 dBmop/600 Ohms of demodulated level along the line differential mode (DM),and typically 50 dBA on acoustic level at the earphone

Source: CSELT / SIP

EMC considerations for fixed telephones in Italy

1 - Introduction

Some SMG2 documents have been produced up to now on the potential disturbances of GSM transmitters on fixed telephones in UK (SMG2 Tdoc. 52/93), in France (SMG2 Tdoc. 89/93) and in Norway (SMG2 Tdoc. 100/93).

This document adds some information to the problem, by discussing the results of some tests performed in Italy using a set of fixed telephones interfered by GSM emissions at different power.

2 - Measurement procedure

The immunity of fixed telephones to the interference of GSM emissions was measured in two different environments: a GHz-TEM cell and a properly equipped flat roof.

2.1 - Generation of the GSM interference

Most experiments were carried out using an interfering signal produced by a transportable GSM mobile equipment communicating with a base station at a constant power level (since the power control function of the GSM was not active during the test). A portion of the GSM signal was split by a 20 dB directional coupler and sent to the radiating antenna through an RF power amplifier. The signal power level at the antenna was regulated by a variable attenuator and checked by means of a peak power meter.

Other experiments were also performed by emulating the GSM emission through a sine-wave (generated by means of a frequency synthesiser) modulated by pulses (produced by an arbitrary waveform generator). Two modulating signals were considered: a pulse reproducing the GSM frame (repetition rate equal to 216.6 Hz, duty cycle of 1/8, guard time equivalent to that of GSM bursts) and a 200 Hz square wave with a duty cycle of 50%.

2.2 - Performance criteria for the immunity tests

The following parameters were used in order to evaluate the immunity of the fixed telephone to radiated or conducted interferences.

- Noise rejected along the line (expressed in dBmop on 600 Ω), measured by a psophometer and weighted by CCITT curve. A maximum value of -50 dBmop is consistent with the current trend in CENELEC standards.

- Level of the acoustic disturbance (expressed in dB-SPL, weighted with the A curve) listened by an artificial ear coupled with the handset. Even if no limits are currently specified, on the basis of laboratory experience, a level of 60 dB-SPL can be considered clearly audible, while a level of 70 dB-SPL gives trouble to the conversation.

2.3 - Test setup

Formal tests were carried out in a GHz-TEM cell using the block diagram shown in fig. 1; the devices under test were interfered by a vertically-polarised plane-wave produced by a radiating element fed by the GSM test signal. The acoustic disturbance was measured by an audio analyser connected to an artificial ear, while the noise rejected along the line was measured by a psophometer. A preliminary calibration of the electrical field strength was performed by using a continuous wave signal, whose equivalence with the level of the GSM stimulus was established by means of a peak power meter. Measurement have been performed for electrical field strength of 3, 6, 10 and 15 V/m.

The correspondence between the electrical field measured in the GHz-TEM cell and the power transmitted by a GSM mobile was verified separately on a properly equipped flat roof covered with a metal plating and supplied with panels of absorbing material, which attenuate the scattering from other directions. It has been verified that the electrical field values measured at one meter distance from the calibrated dipole had a good correspondence with the expected values of the transmitted power (~6 V/m for 0.8 W, ~10 V/m for 2 W, ~16 V/m for 5 W and ~20 V/m for 8 W).

The equipped flat roof was also used for informal tests: the devices under test were placed on a wooden and plastic support. Some experiments were carried out with the same stimuli as those used in the GHz-TEM cell, transmitted by a calibrated electric dipole mounted on a tripod. Other informal experiments were performed by a man bringing the active GSM transmitters (hand held and portable) directly near the device under test. The disturbances on the fixed telephones were measured in the same way as in the GHz-TEM cell case.

3 - Test results

A certain number of telephones commonly used in the Italian public network were tested both using the GHz-TEM cell and the equipped flat roof.

As far as the GHz-TEM cell is concerned, figs. 2 and 3 show respectively the noise rejected along the line and the level of the acoustic disturbance vs. the electrical field strength of the GSM interferer. Telephones labelled as T1, T2, T6, T7 are samples produced by different manufacturers of a

very common model in Italy. The wide spread between the curves (more than 10 dB) can be justified by the different sensitivity of the electronic devices put on the circuit boards of the telephones, by a slightly different arrangement of the device under test and of its wires and by the uncertainty of the measuring equipment. The shape of the telephone labelled as T3 looks like that of the previous ones, but its circuits are shielded by a metallic box, making it suitable for strong electromagnetic interference environments. Its immunity (rejected noise lower than -50 dBmop and acoustic level of the order of 50 dB-SPL) is higher than that of the previous models. An immunity of the same order of magnitude was also achieved by a rugged and compact model (labelled T5) without any peculiar shielding. The lowest immunity to the radiation was instead obtained by the model labelled T4, which uses more sophisticated electronics for the automatic answering function.

It is worthwhile noting that the sensitivity to the GSM interference was caused in all cases by the electronic circuitry of the fixed telephones; in fact the tests performed on an old electro-mechanical analogue telephone did not detect any kind of disturbance, even with very high interfering transmitted power (up to 20 W).

The immunity of two selected telephones (T1 and T3) to the GSM interference was also compared with the immunity to different stimuli (GSM-like emulated signal and sine-wave modulated by a 200 Hz square-wave). The results of the comparison are shown in figs. 4 and 5 respectively for the noise rejected along the line and the level of the acoustic disturbance. Note that the spread between the curves is narrow, even if the true-GSM case results slightly worse.

For the same selected telephones, figs. 6 and 7 compare the immunity parameters (noise rejected along the line and level of the acoustic disturbance) measured in the GHz-TEM cell with those measured on the roof. The levels of the electric field measured in the GHz-TEM cell have been translated to power values in order to use the same scales for the two environments. The measurements on the roof have been performed with the dipole vertically and horizontally polarised and with the telephone kept vertical and horizontal, 1 m far from the dipole. The spread between the curves is wide (more than 10 dB), showing that the position of the interferer is crucial. The closest results between the two environments have been obtained when using the same physical conditions (telephone put in horizontal position and radiating antenna with vertical polarisation), while the worst results have been detected when putting the telephone in vertical position and using a radiating antenna with horizontal polarisation, which, on the other hand, is a very unusual arrangement.

4 - Conclusions

From the performed measurements, it results that the disturbances on the fixed telephones are due to the impulse shape of the TDMA GSM transmission processed by the electronic circuitry of such telephones. Therefore, only the old electro-mechanical analogue telephones are immune from the GSM interference, while all the other current equipment is susceptible to close distance GSM emissions, showing a strong dependence from the power of such an emission.

Simple and reliable measurements done with pulsed sine-waves give immunity results quite similar to the true-GSM case. This measurement technique can therefore be proposed as an effective alternative for the immunity tests of the telephones when only low cost, general purpose instrumentation is available (for instance for telephone manufacturers).

Out of the tested fixed telephones, just an RF-shielded model and another with a very compact structure resulted complying with immunity requirements up to 6 V/m GSM field strength (that is 0.8 W GSM emission at 1 m distance), while some models did not even comply with 3 V/m (i.e. 0.8 W GSM emission at 2 m distance).

The recent decisions made in SMG#7 to leave just the two lowest classes for GSM hand-held units (0.8 W and 2 W) and to assign the remaining two classes (5 W and 8 W) to the vehicle/portable mobiles are then also supported by the above considerations.

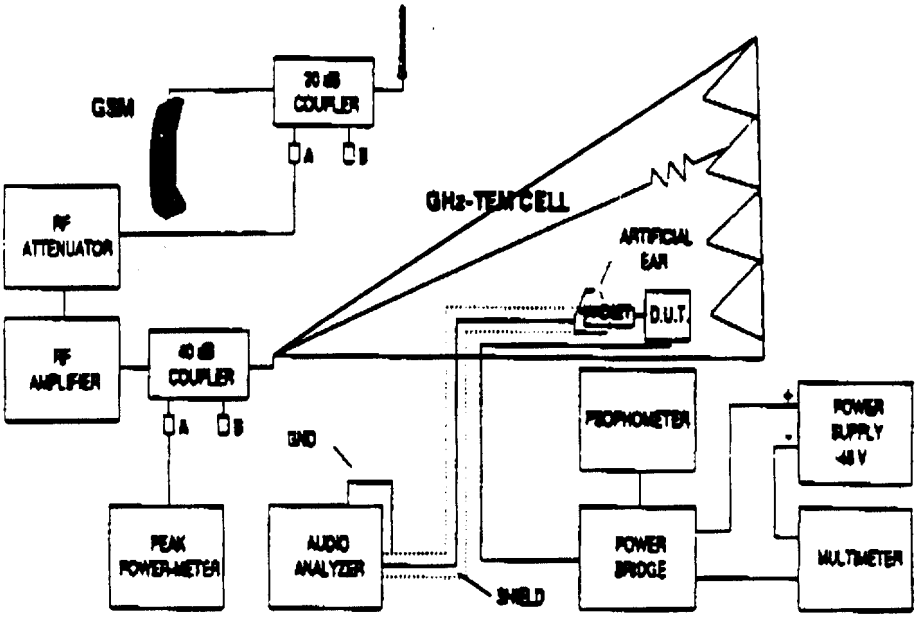

Fig. 1 Representation of the experimental setup for the measurements in the GHz-TEM Cell

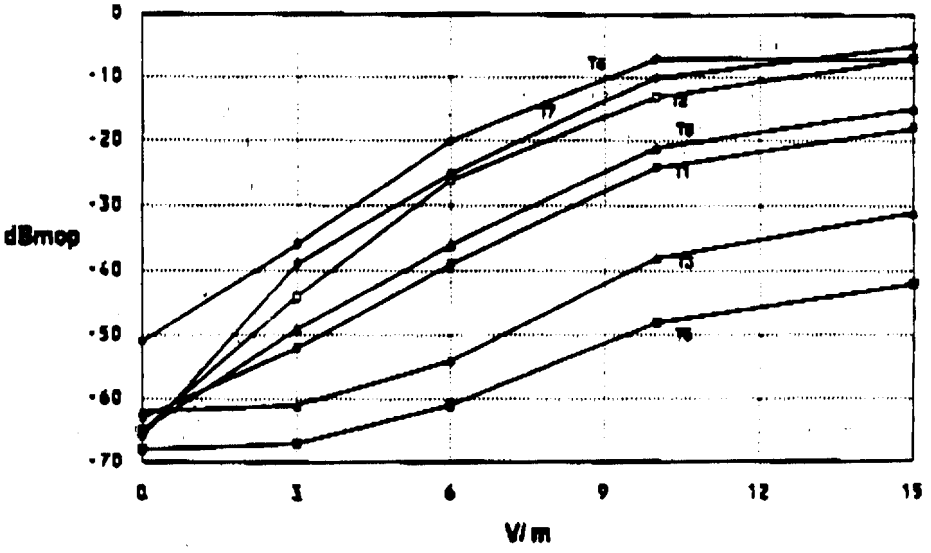

Fig. 2 Rejected noise along the line for the measured telephones in the GHz-TEM cell with the GSM signal.

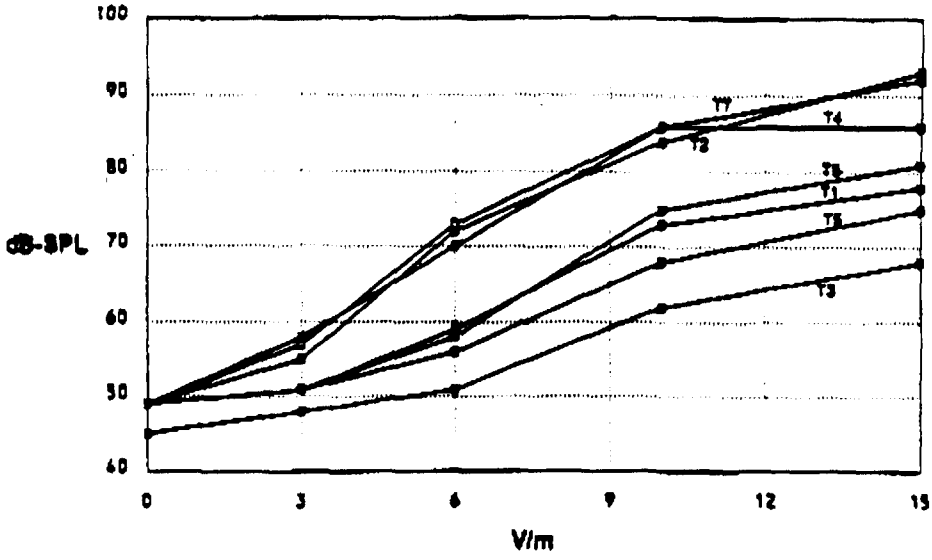

Fig. 3 Level of the acoustic disturbance for the measured telephones in the GHz-TEM cell with the GSM signal.

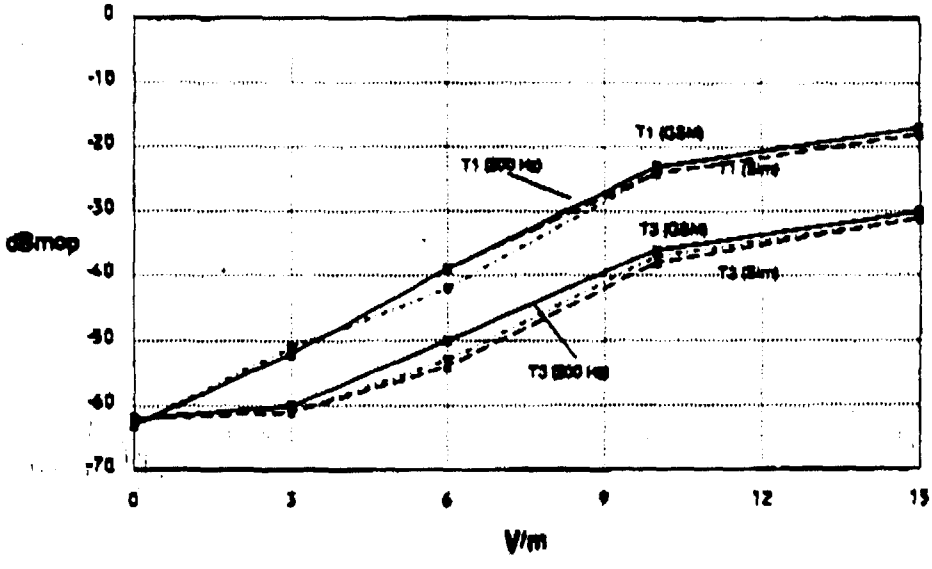

Fig. 4 Rejected noise along the line for two samples of telephones in the GHz-TEM cell with the GSM signal (straight line), the GSM pulse simulation and the 200 Hz square wave pulse modulation (dotted lines).

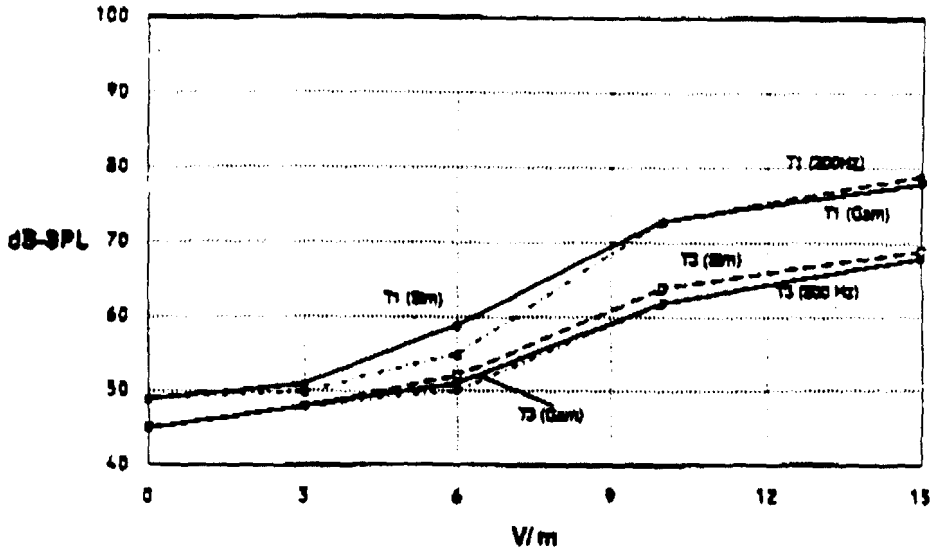

Fig. 5 Level of the acoustic disturbance for for two samples of telephones in the GHz-TEM cell with the GSM signal (straight line), the GSM pulse simulation and the 200 Hz square wave pulse modulation (dotted lines).

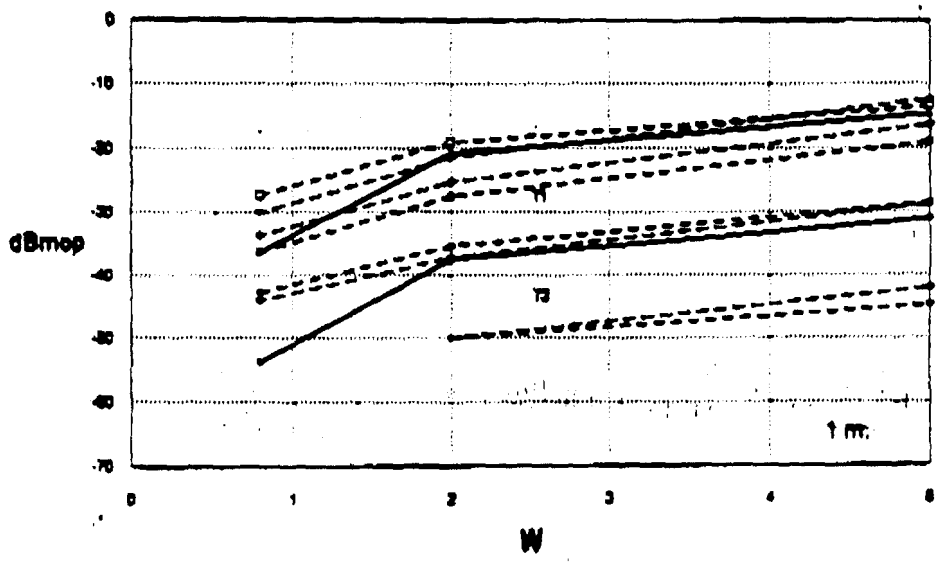

Fig. 6 Rejected noise along the line for two samples of telephones in the GHz-TEM cell with the GSM signal (straight line) and in the roof environment for various antenna polarisations and phone positions (dotted lines).

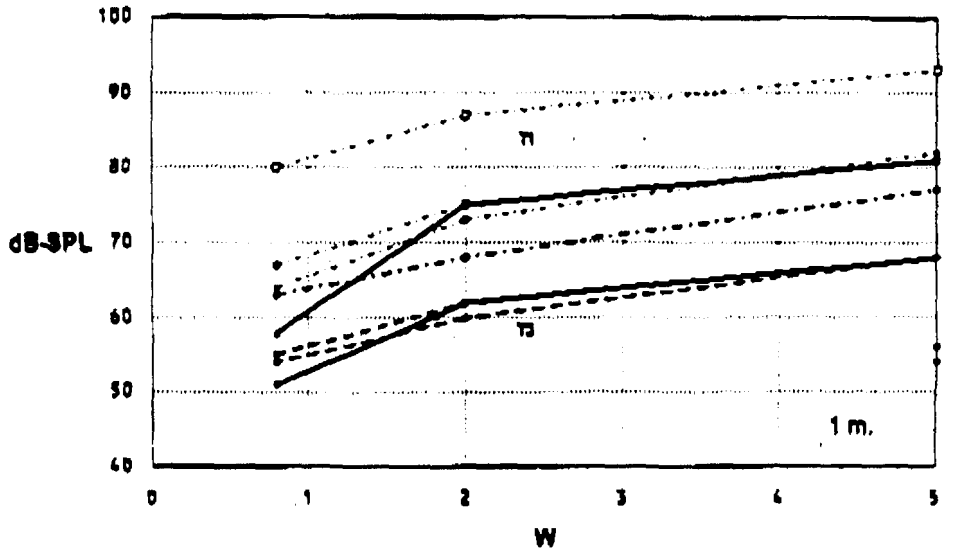

Fig. 7 Level of the acoustic disturbance for two samples of telephones in the GHz-TEM cell with the GSM signal (straight line) and in the roof environment for various antenna polarisations and phone positions (dotted lines).

TF Televerkets Forskningsinstitutt

Tittel Interferens fra TDMA-strukturene i digital mobilkommunikasjon på PSTN	**TF-rapport** R 40/92 **ISBN** 82-423-0230-8 **ISSN** **Prosjekt nr** **Innsatsområde** Mobilkommunikasjon **Tilgjengelighet** Åpen **Antall sider** 28 **Dato** 921006
Forfattere Egil Hauger	

Emneord
EMC TDMA Mobilkommunikasjon

Sammendrag

Rapporten tar for seg TDMA - Time Division Multiple Access - strukturen i GSM og DECT systemene og påpeker faren for hørbar interferens i elektronisk utstyr med audio-utgang. Det er forestatt interferens måling på 12 godkjente telefonapparater og resultatene viser en meget stor spredning i immuniteten.

GSM-systemet vil gi sjenerende interferens i mange av telefonene på flere meters avstand.

Title

Interference from the TDMA structure in digital mobile communication to PSTN

Abstract

The report deals with the TDMA - Time Division Multiple Access - structure in the GSM and DECT systems and pays attention to the risk of audible interference in electronic devices with audio output. For 12 type approved analog PSTN telephone sets, the interference has been measured and the results show a great variation in immunity level.

The GSM system will give rise to harmful interference in many of the examined telephone sets for a distance of many metres.

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Det må ikke kopieres fra denne rapport utover det som er tillatt etter bestemmelsene i "Lov om opphavsrett til åndsverk", "Lov om rett til fotografi" og i "Avtale mellom staten og rettighetshavernes organisasjoner om kopiering av opphavsrettslig beskyttet verk i undervisningsvirksomhet".

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3 Measurement set-up, method of measurement .....

4 Measurements results for GSM-TDMA structure .....
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5 Measurements results for DECT-TDMA structure .....

6 Conclusion .....

Annex 1 - 15

1 Introduction

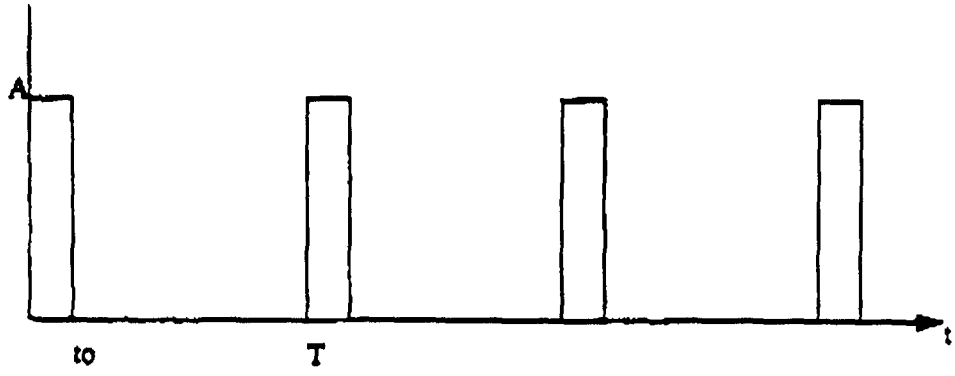
TDMA, Time Division Multiple Access, is becoming widely used in modern digital radio, particularly for mobile communication. In this way the carrier can be shared by a number of users. In GSM, the new digital mobile communication developed by ETSI, a 900 MHz carrier is divided into 8 slots for 8 different mobile users. Each timeslot is 0.5428 ms with a repetition frequency of 217 Hz. In the remaining OFF condition when the 7 other users are on air, the 900 MHz carrier is to be below 70 dB referred to the ON condition.

From an interference point of view, this is an amplitude modulation which has the possibility to create a lot of interference in other electronic devices. Analog mobile communication such as NMT and TACS has a constant RF envelope with narrowband frequency modulation and other electronic devices are not sensitive to these RF signals.

Serious interference is mainly due to rapid changes in the envelope of the high frequency interferer and therefore all kinds of amplitude modulation of a potential interferer will increase the risk for incompatibility between systems using radio communication and other IT-equipment.

2 TDMA, Demodulated frequency spectrum

The RF spectrum from one mobile may be like fig 1 below. This is the RF burst from a GSM mobile in the 900 MHz frequency band.



to=0.577 ms

T=4.615 ms

Figur 2.1: TDMA structure for GSM

The amplitude of the frequency spectrum is now given by

$$F(f) = \sum_{0}^{\infty} 2A\frac{t_0}{T}\left|\frac{\sin\frac{n\pi t_0}{T}}{\frac{n\pi t_0}{T}}\right| \qquad (2.1)$$

The relative spectrum is shown in annex 1. As can be seen, there is a component for each 217 Hz and the spectrum has zeroes given by T/to times the pulse repetition frequency.

In the same way we can calculate the TDMA spectrum for the DECT system. Here the RF pulse duration is 0.4167 ms with a pulse repetition frequency of 100 Hz. This relative frequency spectrum is given in annex 2. This TDMA structure gives a component for each 100 Hz with zeroes for each T/to (= 24) times 100 Hz.

The spectrum from this TDMA structure gives most of the demodulated energy in the audio frequency band. Therefore there is a great risk that such TDMA signals give audible interference in electronic devices intended for audio output such as hearing aids and ordinary PSTN telephone set.

In this report we will give results from measurements on type approved analog PSTN sets.

3 Measurement set-up, method of measurement

For the time being there is no existing requirement for immunity of analog telephone sets. Therefore there is no standardized measurement set-up and method of measurements.

In the frequency band we are talking about, 1 GHz and above, the generation of the RF-field and how the field is coupled to the victim's electronic circuit is of greatest importance to the interference results. Our suggestion is that the measurement should be as "real life" as possible and therefore much effort is given to assure a reproduceable and realistic immunity test which gives as exact as possible the interference level the user can, in the worst case, be exposed to.

Annex 3 gives the overview of the instrument set-up in a semi-anechoic chamber. During the measurement we realized the very importance of positioning the telephone set and the transmit antenna. The telephone set was placed on a turntable for rotation 0-360 dgr and the antenna was rotated in the horizontal and vertical position in the height from 0.95 to 2.20 m.

The highest interference level occurred at an exact position of both the telephone and the antenna indicating that the RF-field was coupled to the PCB of the telephone and not induced via telephone line or handset cable. In an ordinary desk telephone where the PCB is horizontal the interference level was much higher for horizontal polarized field than for vertical, although the telephone line and the handset cable were vertical as shown on the set-up.

Now the antenna in a mobile system is foreseen to be vertical, but when using a handheld mobile set, the angle to the vertical is about 65 degrees and in practice the angle can be in the whole range from 0 to 90 degrees. For car mounted antennas, the angle should be nearly 0 degrees to the vertical, but even here the antenna may be more horizontal because of the convenient capasitive coupled window antenna. When using a one piece telephone set, the angle can of course be the same for the fixed and the mobile telephone.

The measurements are taken at a distance of 3 m from the interferer antenna to the telephone. In this frequency band the far field distance is less than 0.25 m, so you can easily calculate the interference level for any distance of interest.

The interference level was measured both at receive and transmit side of the fixed telephone. On the receive side, the interference was weighted with A-filter and on transmit side the psophometer filter was used.

Due to the high electric field, and problem of filtering to the anechoic chamber, we had to use a passive acoustic coupler with tight coupling. This tight coupling had of course some influence of the frequency response of the handset, but when using the A-filter the influence was minimized. A typical frequency response is given in annex 4 for telephone set no 8.