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TROISIÈME IMPRESSION 1992

THIRD IMPRESSION 1992

Compatibilité électromagnétique pour les matériels de mesure et de commande dans les processus industriels

Partie 3:
Prescriptions relatives aux champs de rayonnements électromagnétiques

Electromagnetic compatibility for industrial-process measurement and control equipment

Part 3:
Radiated electromagnetic field requirements

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY FOR INDUSTRIAL-PROCESS MEASUREMENT AND CONTROL EQUIPMENT

Part 3: Radiated electromagnetic field requirements

FOREWORD

1) The formal decisions or agreements of the I E C on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the I E C expresses the wish that all National Committees should adopt the text of the I E C recommendation for their national rules in so far as national conditions will permit. Any divergence between the I E C recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by I E C Technical Committee No. 65: Industrial-process Measurement and Control.

It forms Part 3 of I E C Publication 801.

The text of this standard is based on the following documents:

Six Months' Rule	Report on Voting
65(CO)28	65(CO)31

Further information can be found in the Report on Voting indicated in the table above.

ELECTROMAGNETIC COMPATIBILITY FOR INDUSTRIAL-PROCESS MEASUREMENT AND CONTROL EQUIPMENT

Part 3: Radiated electromagnetic field requirements

1. Scope

This part is applicable to the susceptibility of industrial-process measurement and control instrumentation to radiated electromagnetic energy. It additionally establishes severity levels and the required test procedures.

2. Object

The object of this part is to establish a common reference for evaluating the performance of industrial-process measurement and control instrumentation when subjected to electromagnetic fields such as those generated by portable radio transceivers (walkie-talkies) or any other device that will generate continuous wave radiated electromagnetic energy.

Note. — Test methods are defined in this part for measuring the effect that electromagnetic radiation has on the equipment concerned. The simulation and measurement of electromagnetic radiation is not adequately exact for quantitative determination of effects. The test methods defined are structured for the primary objective of establishing adequate repeatability of results at various test facilities for qualitative analysis of effects.

These differences shall be taken into account when verification testing is conducted.

3. General

Most electronic equipment is in some manner affected by electromagnetic radiation. This radiation is frequently generated by the small hand-held radio transceivers that are used by operating, maintenance and security personnel. The susceptibility of industrial-process measurement and control instrumentation to the radiation of the hand-held transceiver is the primary concern of this part.

However, other sources of electromagnetic radiation are involved, such as fixed station radio and television transmitters, vehicle radio transmitters and various industrial electromagnetic sources.

In addition to the continuous form of electromagnetic energy deliberately generated, there is also spurious radiation caused by devices such as welders, thyristors, fluorescent lights, switches operating inductive loads, etc. For the most part, this interference manifests itself as conducted electrical interference and, as such, is dealt with in other parts of the standard. Methods employed to prevent effects from continuous radiation will normally also reduce the effects from these sources.

The electromagnetic environment is determined by the strength of the electromagnetic field (field strength in volts per metre). The field strength is not easily measured without sophisticated instrumentation nor is it easily calculated by classical equations and formulae because of the effect of surrounding structures or the proximity of other equipment that will distort and/or reflect the electromagnetic waves.

4. Definitions/Terminology

4.1 *Antenna*

A transducer which either emits radio frequency power into space from a signal source or intercepts an arriving electromagnetic field, converting it into an electrical signal.

4.2 *Broad-band emission*

An emission having a spectral energy distribution sufficiently broad, uniform, and continuous for the response of the measuring receiver in use, not to vary significantly when tuned over a specified number of receiver impulse bandwidths.

4.3 *Conducted emission*

Desired or undesired electromagnetic energy which is propagated along a conductor. Such an emission is called "conducted interference" if it is undesired.

4.4 *Continuous waves (C.W.)*

Electromagnetic waves, the successive oscillations of which are identical under steady-state conditions, which can be interrupted or modulated to convey information.

4.5 *Degradation*

In susceptibility specification testing, degradation is an unwanted change in the operational performance of a test specimen. This does not necessarily mean malfunction or catastrophic failure. The E.M.I. test specification generally requires stating the criteria for degradation of performance.

4.6 *Dipole*

An antenna consisting of a straight conductor (usually not more than a half-wavelength long), divided at its electrical centre for connection to a transmission line.

4.7 *Electromagnetic compatibility (E.M.C.)*

E.M.C. is the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to that environment or to other equipment.

4.8 *Electromagnetic interference (E.M.I.)*

E.M.I. electromagnetic disturbance which manifests itself in performance degradation, malfunction, or failure of electrical or electronic equipment.

4.9 *Electromagnetic wave*

The radiant energy produced by the oscillation of an electric charge characterized by oscillation of the electric and magnetic fields.

4.10 *Emission*

Electromagnetic energy propagated from a source by radiation or conduction.

4.11 *Far field*

That region where the power flux density from an antenna approximately obeys an inverse square law of the distance.

For a dipole this corresponds to distances greater than $\lambda/2\pi$ where λ is the wavelength of the radiation.

4.12 *Field strength*

The term "field strength" shall be applied only to measurements made in the far field. The measurement may be of either the electric or the magnetic component of the field and may be expressed as V/m, A/m or W/m^2; any one of these may be converted to the others.

Note. – For measurements made in the near field the term "electric field strength" or "magnetic field strength" shall be used according to whether the resultant electric or magnetic field, respectively, is measured.

In this field region the relationship between the electric and magnetic field strength and distance is complex and difficult to predict, being dependent on this specific configuration involved. Inasmuch as it is not generally feasible to determine the time and space phase relationship of the various components of the complex field, the power flux density of the field is similarly indeterminate.

4.13 *Frequency band*

A continuous range of frequencies extending between two limits.

4.14 *Induction field*

The predominant electric and/or magnetic field existing at a distance, $d < \lambda/2\pi$, where λ is the wavelength.

4.15 *Isotropic*

Having properties of equal values in all directions.

4.16 *Monopole*

An antenna consisting of a straight conductor (usually not more than one-quarter-wavelength long) mounted immediately above, and normal to, an imaging (ground) plane. It is connected to a transmission line at its base and behaves, with its image, like a dipole.

4.17 *Polarization*

A term used to describe the orientation of the electric field vector of a radiated field.

4.18 *Radiated emission*

Radiation and induction field components in space.

4.19 *Radiation*

The propagation of a signal or interference from a source other than by conduction.

4.20 *Radio environment*

The combined effect of the radio emissions that are created at any given location by normally operating authorized transmitters. It has the dimension of field strength and varies with frequency band, geographical location and time.

4.21 *Radio-frequency interference (R.F.I.)*

R.F.I. used interchangeably with E.M.I. E.M.I. is a later definition which includes the entire electromagnetic spectrum, whereas R.F.I. is more restricted to the radio-frequency band, generally considered to be between 10 kHz and 10 GHz.

4.22 *Shielded enclosure*

A screened or solid metal housing designed expressly for the purpose of isolating the internal from the external electromagnetic environment.

The purpose is to prevent outside ambient electromagnetic fields from causing performance degradation and to prevent emission from causing interference to outside activities.

4.23 *Stripline*

Parallel plate transmission line to generate an electromagnetic field for testing purposes.

4.24 *Spurious radiation*

Any undesired electromagnetic emission from an electrical device.

4.25 *Susceptibility*

The characteristic of electronic equipment that results in unwanted responses when subjected to electromagnetic energy.

4.26 *Sweep*

A continuous traverse over a range of frequencies.

4.27 *Transceiver*

The combination of radio transmitting and receiving equipment in a common housing.

5. Severity levels

Frequency band: 27 MHz to 500 MHz

Level	Test field strength (V/m)
1	1
2	3
3	10
x	Special

Note. – x is an open class.

6. Selection of test methods

The test methods contained in this part are the usual methods employed in conducting E.M.I. radiated susceptibility tests, and because of the magnitude of the field strengths generated, they shall be conducted in a shielded room in order to comply with various national and international laws prohibiting interference to radio communications. In addition, since most test equipment used to collect data is sensitive to the local ambient electromagnetic field generated during the execution of the susceptibility test, the shielded enclosure provides the necessary "barrier" between the equipment under test (E.U.T.) and the required test instrumentation. Care needs to be taken to ensure that the interconnection cabling penetrating the shielded enclosure adequately attenuates the conducted radiated emission and preserves the integrity of the E.U.T.'s signal and power responses.

6.1 *Shielded enclosures*

The use of a shielded enclosure has always caused a high degree of controversy during the development of any E.M.I. standard. Specifically, the issue of standing waves and the resultant potential for erroneous results have been intensively discussed.

In comparing the available alternative methods (anechoic chambers, transverse electromagnetic (T.E.M.) cells, mode-stirred chambers, open antenna ranges, stripline), the use of shielded enclosures was retained because it is the most efficient means of performing radiated measurements that is in widespread use.

Since most occurrences of susceptibility are relatively broad band, a qualitative analysis of data will in most cases be quite adequate. If a radiated field peaks at 150 MHz, causing a malfunction in the operation of electronic equipment, the equipment will most likely malfunction at 145 MHz or 155 MHz or anywhere near 150 MHz when tested in a different shielded room. For devices which are narrow-band (i.e. a low level internal oscillator), radiated field nulls at the location of the equipment under test and at the frequency of the oscillator may provide an apparent negligible influence when in fact the equipment may be susceptible. The wide excursions of field strengths are greatly alleviated by the use of one or more monitoring antennae near the test sample. As peaks and nulls are encountered, the field strength can be readjusted to the required level. The influence of standing waves can be additionally controlled by the geometry of the enclosure, the removal of non-required objects in the enclosure, and partial anechoic shielding.

Finally, the qualitative evaluation of any resultant data needs to be assessed in terms of the existing local ambient electromagnetic level and the specific operating frequencies. For example, an equipment's susceptibility at 75 MHz is of no consequence if the operating communication frequency at the equipment site is 450 MHz.

6.2 *Anechoic chambers*

Anechoic chambers are inefficient at frequencies below 100 MHz. To be effective at 100 MHz, anechoic chambers require absorbers approximately 2 m thick. Above 100 MHz, the use of an anechoic chamber will substantially reduce reflection errors. It is by far the most preferred type of enclosure.

6.3 *Stripline circuit*

The uniform field produced between the plates of a parallel stripline is a desirable feature in conducting susceptibility measurements.

The parallel stripline specified in MIL-STD-461 and 462 standards is of limited application due to the restricted plate separation (50 cm with maximum object height of 25 cm) and the maximum frequency of operation of 35 MHz. Another design (Groenveld and de Jong) with dimensions of 80 cm × 80 cm × 80 cm has been reported by the Electrical Research Association (E.R.A.) of Great Britain as being usable up to 500 MHz (reference: E.R.A. Report No. 80-135). This part considers only this second apparatus.

This apparatus is potentially usable for small objects (in the order of one-third of the dimensions of the stripline). For objects with larger dimensions, it is possible to have inhomogeneity of the field. Similar problems exist when large equipment is located in small shielding enclosures or anechoic chambers.

Notes 1.– In addition to the test methods described in Clause 6, other methods are in use. Examples of these methods are listed in Appendix A.

2.– *Field strength measurements* – It is fairly usual to establish the required field strength by utilizing a receiving antenna and subsequently replacing it with the E.U.T. However, it is felt that the time required using this approach is prohibitively expensive, and its relative merits questionable especially when account is taken of the fact that the replacement of the receiving antenna with the E.U.T. distorts the original field. Continuous monitoring of the existing field strength and readjustment of power levels is therefore advocated.

7. Test equipment

The following types of test equipment are recommended:

1) Shielded room or anechoic chamber; size adequate to maintain distances specified in Figure 1, page 24.
2) Stripline circuit (27 MHz to 500 MHz).
3) Signal source: signal generator(s) capable of covering frequency range and having automatic sweep capability of 0.005 octave/s (1.5×10^{-3} decades/s) or slower.
4) Power amplifier: to amplify signal and provide antenna drive if signal source is incapable.
5) Antennae: signal source
   a) biconical: 27 MHz to 200 MHz
   b) conical logarithmic spiral: 200 MHz to 500 MHz
   c) or any other antenna system capable of satisfying frequency requirements.
6) Field strength monitors
   a) isotropic.
7) Associated equipment to monitor output and to establish operating power and signals for test sample.

Note. – The use of other means of establishing and controlling the field is not ruled out and is acceptable providing the required conditions can be verified.

8. Test set-up

The procedure defined in this part requires the generation of electromagnetic fields within which the test sample is placed and its operation observed. To generate fields that are useful for simulation of actual (field) conditions may require significant antenna drive power and the resultant high field strength levels. To comply with local regulations and to prevent biological hazards to the testing personnel, it is recommended that these tests be carried out in a shielded enclosure or anechoic chamber.

The use of a shielded enclosure, however, creates difficulties in establishing and maintaining the required field strengths due to reflections of the radiated energy from the walls of the enclosure.

These reflections will cause reinforcement (peaks) and cancellation (nulls) to be established within the room. To alleviate the uncertainty regarding the actual field strength present in proximity to the equipment under test, one or more field strength monitors may be required. The size of the shielded enclosure should be commensurate with the size of the equipment under test in order to achieve adequate control over the established field strengths.

All testing of equipment shall be performed in conditions as close as possible to installed conditions. Wiring shall be consistent with the manufacturer's recommended procedures, and the equipment shall be in its housing with all covers and access panels in place, unless otherwise stated.

If the equipment is designed to be mounted in a panel, rack or cabinet, it should be tested in this configuration.

If the wiring to and from the unit is not specified, unshielded twisted-pair wiring shall be used and left exposed to the E.M.R. for a length of 1 m from the point of connection to the E.U.T. After this, the wiring is interfaced with E.M.I. filters and shielded wiring which connects to the test equipment outside the shielded enclosure.

The 1 m length of exposed wiring is run in a configuration which essentially simulates rack wiring; that is, the wiring is run to the side of the E.U.T., then either up or down (at the convenience of the test operator). The horizontal/vertical arrangement helps to ensure worst-case conditions.

8.1 *Shielded room* (Figure 1, page 24)

The equipment under test is placed on a wooden table in the centre of the enclosure. If the E.U.T. is a rack-type item of equipment, it is set directly on the floor but insulated to prevent metallic contact.

The radiating antenna is placed at least 1 m from the front of the E.U.T.

A specific ground plane is not required. When a means is required to support the test sample, it should be constructed of non-metallic material. However, grounding of housing or case of the equipment shall be consistent with the manufacturer's installation recommendations.

8.2 *Stripline circuit* (Figures 2, 3, 4 and 5, pages 26-29)

Small objects (25 cm × 25 cm × 25 cm) can be tested in a stripline circuit. The test object is placed in the centre of the cubicle part of the stripline on a support of foam plastic. The equipment under test shall be tested in three different orientations.

All testing of equipment shall be performed in conditions as close as possible to installed conditions. Wiring should be consistent with the manufacturer's recommended procedures.

The filters on the top of the stripline (Figure 4) are required to protect adequately the E.U.T.'s signal and power lines and reduce conducted interference liable to affect the external test instrumentation (the use of ferrite rings on the external leads is recommended).

9. Test procedures

The test procedures assume the use of biconical and log-spiral antennae or stripline.

Note. – Other methods of establishing fields are acceptable providing the proper fields can be generated and verified.

9.1 *Shielded room*

The equipment to be tested is placed in the centre of the enclosure on a wooden table. The equipment is then connected to power and signal leads according to pertinent installation instructions.

The biconical antenna and the log-spiral antenna are placed 1 m away from the equipment, thus enabling the complete frequency range of 27 MHz to 500 MHz to be traversed without having to change the position of the antennae at the 200 MHz crossover frequency. The required field strength is determined by placing the field strength meter(s) on top of or directly alongside the equipment under test and monitoring the field strength meter via a remote field strength indicator outside the enclosure while adjusting the continuous-wave to the applicable antennae.

The test is normally performed with the antenna facing the most sensitive side of the E.U.T. The polarization of the field generated by the biconical antenna necessitates testing each position twice, once with the antenna positioned vertically and again with the antenna positioned horizontally. The circular polarization of the field from the log-spiral antenna makes a change of position of the antenna unnecessary.

At each of the above conditions, the frequency range is swept from 27 MHz to 500 MHz, pausing to adjust the r.f. signal level or to switch oscillators and antennae. The rate of sweep is in the order of 1.5×10^{-3} decades/s. The sensitive frequencies or frequencies of dominant interest may be discretely analyzed.

9.2 *Stripline circuit*

The equipment to be tested is placed in the centre of the stripline on a support of foam plastic and connected to power and signal leads according to Figure 2, page 26. The stripline is placed 2 m away from walls and any metallic enclosure to prevent reflections. Power and signal lines are connected through filters on the top of the stripline to the equipment under test. Outside the stripline these leads are routed in a vertical position for at least 0.5 m and then horizontally to the place of the associated equipment where the leads are brought down. The associated equipment is placed 2 m away on the axis of the stripline.

The required field strength is determined by reading the voltage between the two parallel plates using a voltmeter connected on a coaxial tee at the input of the stripline. This value is converted into field strength by the calibration factor.

The calibration factor of the stripline might be considered as the frequency response of the relationship between the input voltage and the field strength in the stripline, when measured with an isotropic sensor antenna in the anticipated location for the E.U.T.

The test is performed with the E.U.T. in the most sensitive orientation. The frequency range is swept from 27 MHz to 500 MHz pausing only to adjust the r.f. signal level. The rate of sweep is in the order of 1.5×10^{-3} decades/s.

9.3 *Evaluation of the test results*

The variety and diversity of equipment and systems to be tested make difficult the task of establishing general criteria for the evaluation of the effects of electromagnetic radiation on equipment and systems.

The test results may be recorded on the basis of the operating conditions and the functional specifications of the equipment under test.

The records may comprise, for example:

a) The effect of the electromagnetic field on the output of the E.U.T.,

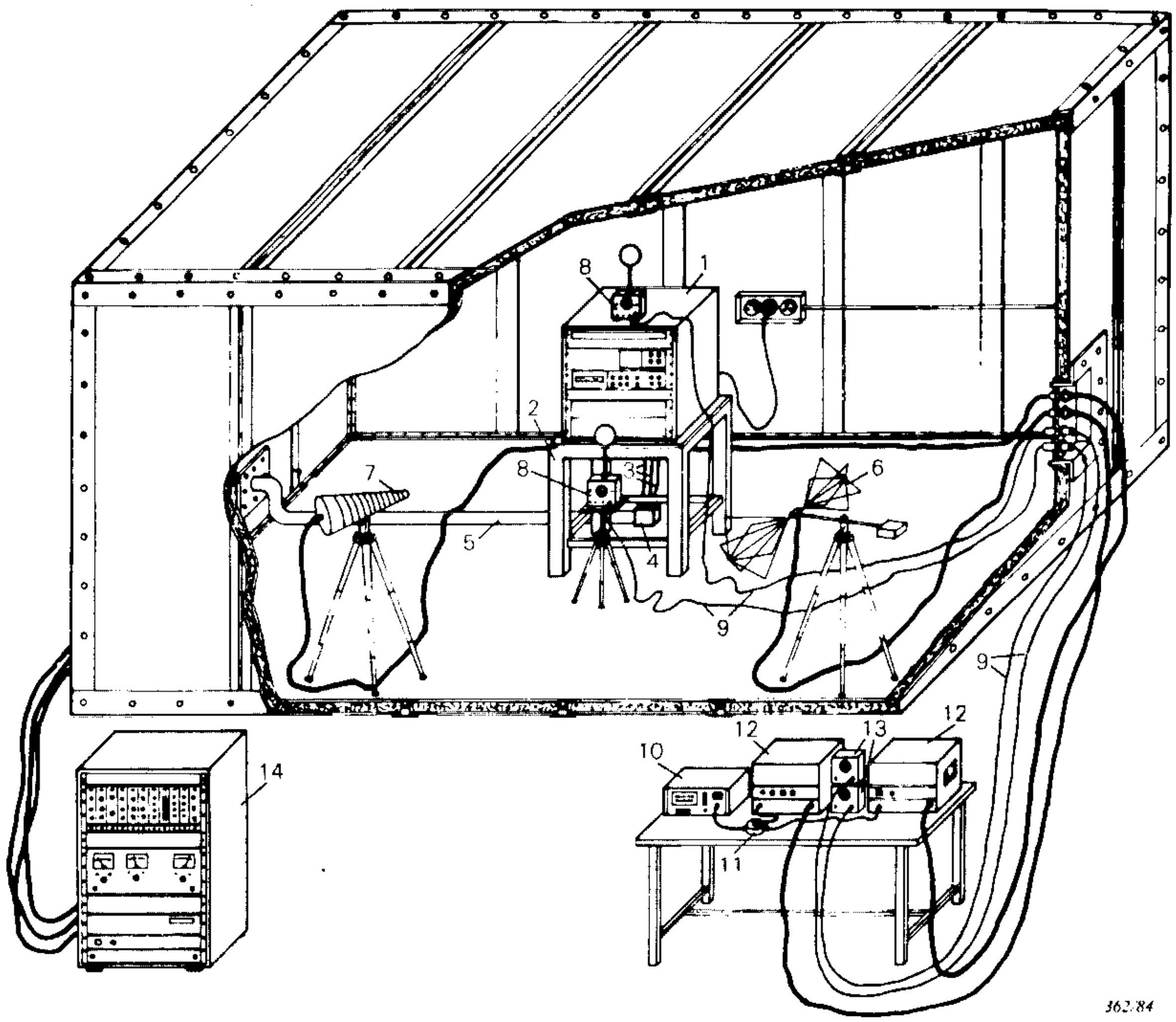
i) as a consistent measurable effect,

ii) as a random effect, not repeatable, and possibly further classified as a transient effect occurring during the application of the electromagnetic field and as a permanent or semipermanent field after the application of the electromagnetic field.

b) Any damage to the E.U.T. resulting from the application of the electromagnetic field.

In the case of acceptance tests, the test programme and the interpretation of the test results are subject to agreement between manufacturer and user.

The test documentation shall include the test conditions and the test results.



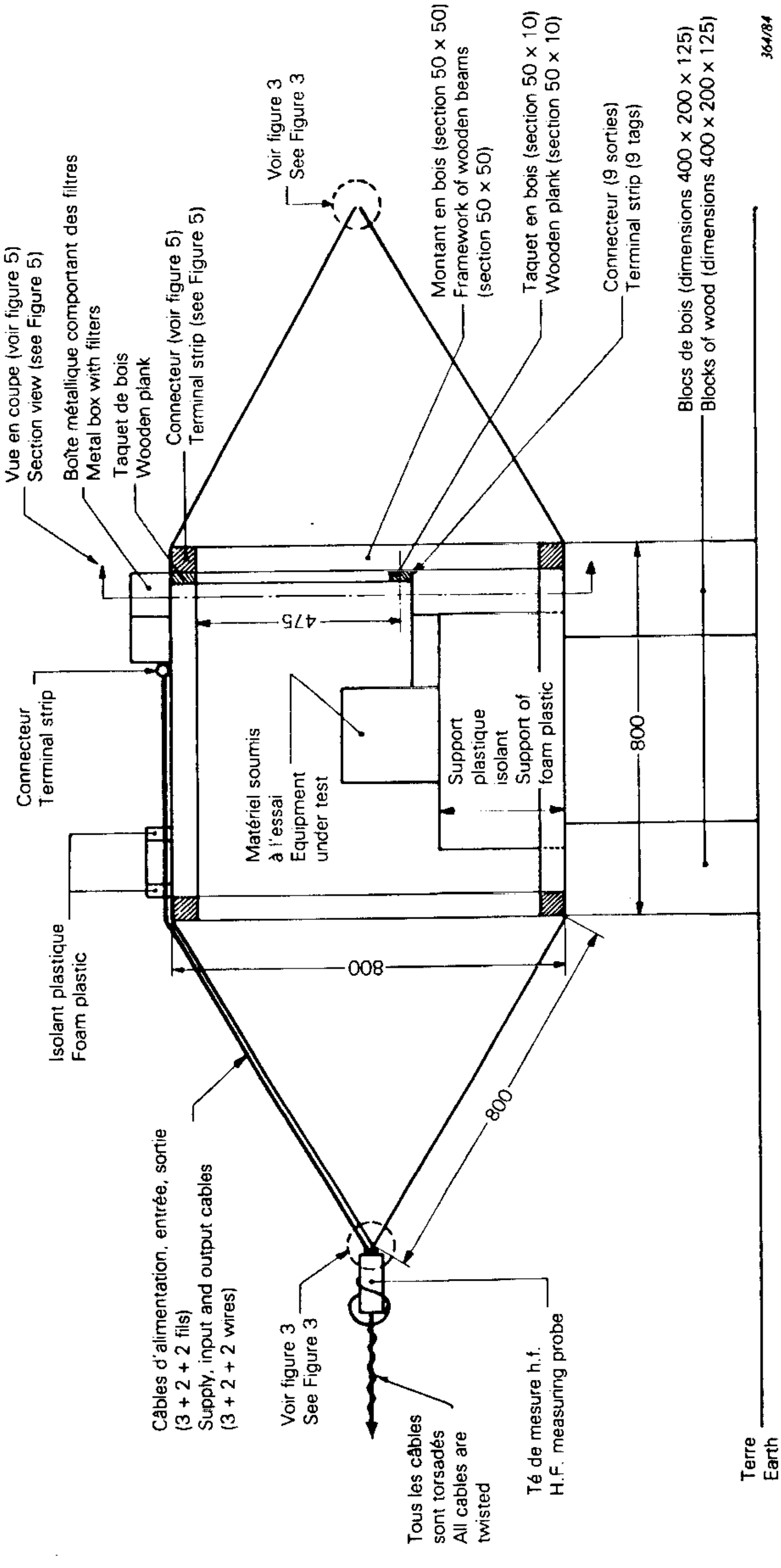
1. E.S.T.: matériel soumis à l'essai
2. Table en bois (H = 1 m)
3. Câblage non blindé à paire torsadée de 1 m de longueur
4. Filtres de perturbations électromagnétiques ou circuits de conditionnement des signaux
5. Conduite métallique pour raccords
6. Antenne 27 MHz à 200 MHz
7. Antenne 200 MHz à 500 MHz
8. Appareils de mesure d'intensité de champ (par exemple avec réponse isotrope)
9. Liaison par fibres optiques
10. Générateur de signaux
11. Interrupteur coaxial
12. Amplificateurs de puissance pour couvrir toute la gamme des fréquences d'essai
13. Répéteurs d'appareils de mesure d'intensité de champ
14. Instrumentation de mesure et simulateur de matériel (si nécessaire) pour l'exploitation de l'E.S.T.

Note. – Il convient que chaque antenne soit placée à 1 m au moins de l'E.S.T. et à 2 m de toute paroi des enceintes métalliques.

1. E.U.T.: equipment under test
2. Wooden table (H = 1 m)
3. Unshielded twisted-pair wiring with 1 m length
4. E.M.I. filters or signal conditioning circuits
5. Metallic conduit for connections
6. 27 MHz to 200 MHz antenna
7. 200 MHz to 500 MHz antenna
8. Field strength meters (with isotropic response)
9. Fibre optic link
10. Signal generator
11. Coaxial switch
12. Power amplifiers for covering the full range of test frequency
13. Field strength meter repeaters
14. Measurement instrumentation and simulator of equipment (if necessary) for E.U.T. operation.

Note. – Each antenna should be placed at least 1 m from E.U.T. and 2 m from any surface of metallic enclosures.

FIG. 1. – Installation d'essai pour essais de champs électromagnétiques rayonnés dans une cabine blindée où les antennes, les contrôleurs d'intensité de champ et l'E.S.T. sont à l'intérieur de la cabine blindée, les appareils de mesure et le matériel associé étant à l'extérieur.
Test set-up for radiated electromagnetic field tests in a shielded room where the antennae, field strength monitors and E.U.T. are inside and the measuring instruments and associated equipment are outside the shielded room.



Dimensions en millimètres

Dimensions in millimetres

FIG. 2. – Banc d'essai du circuit du stripline.
Test set-up with stripline circuit.

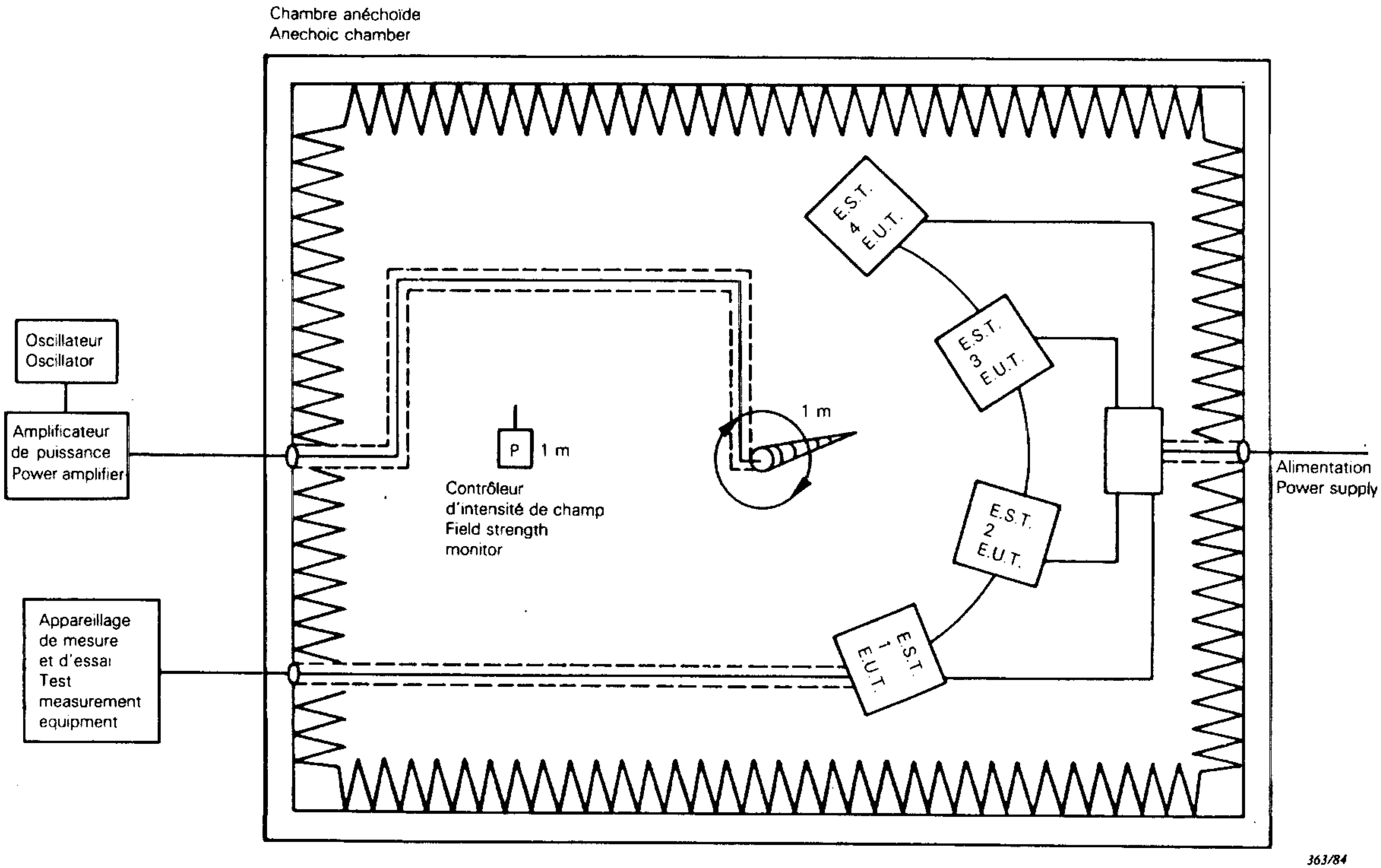


FIG. 1a. – Installation d'essai pour essais de champs électromagnétiques rayonnés dans une chambre anéchoïde, disposition générale de l'E.S.T., du contrôleur d'intensité de champ et des antennes.

Test set-up for radiated electromagnetic field tests in an anechoic chamber, general arrangement of the E.U.T., field strength monitor and antennae.

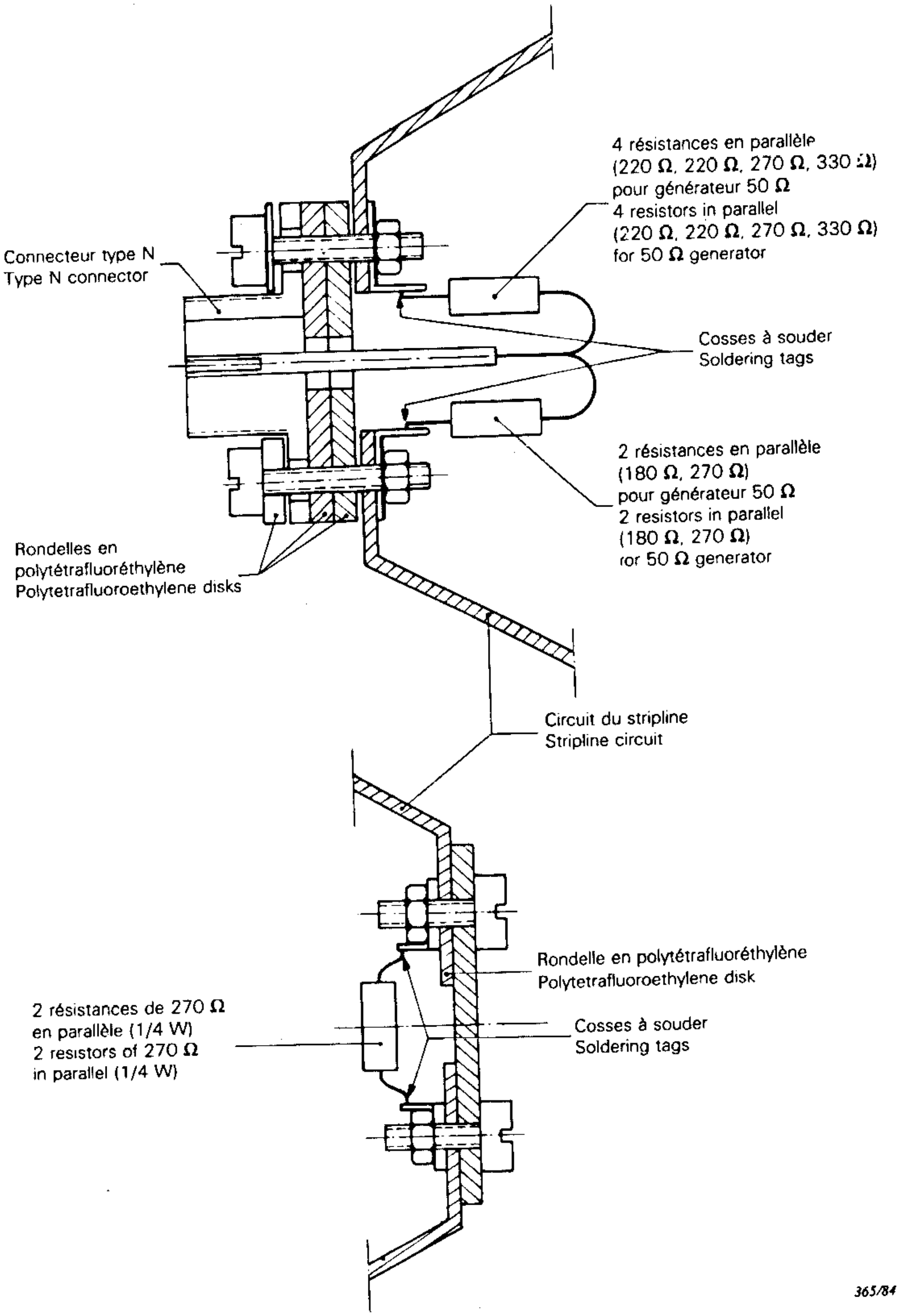
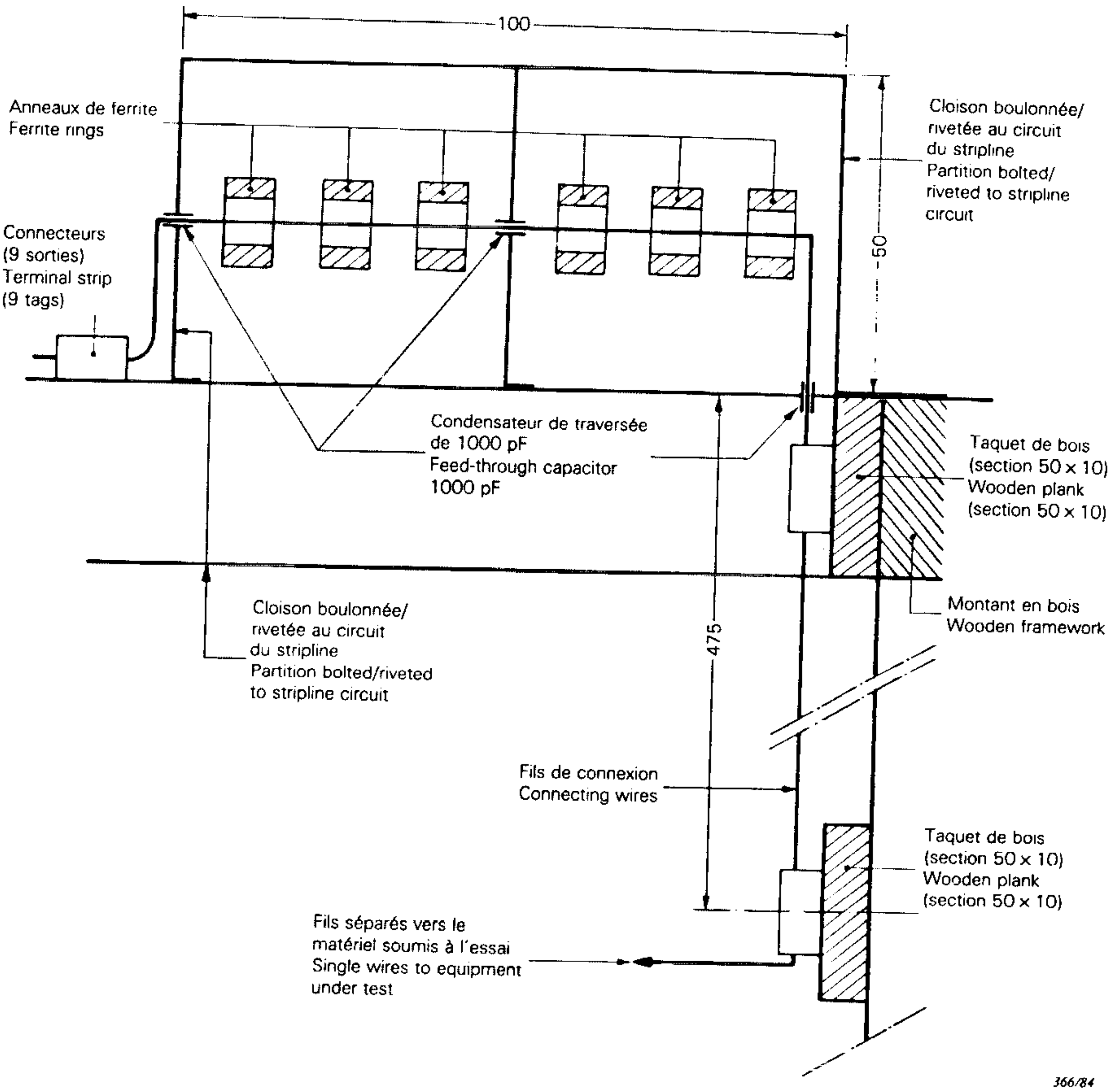
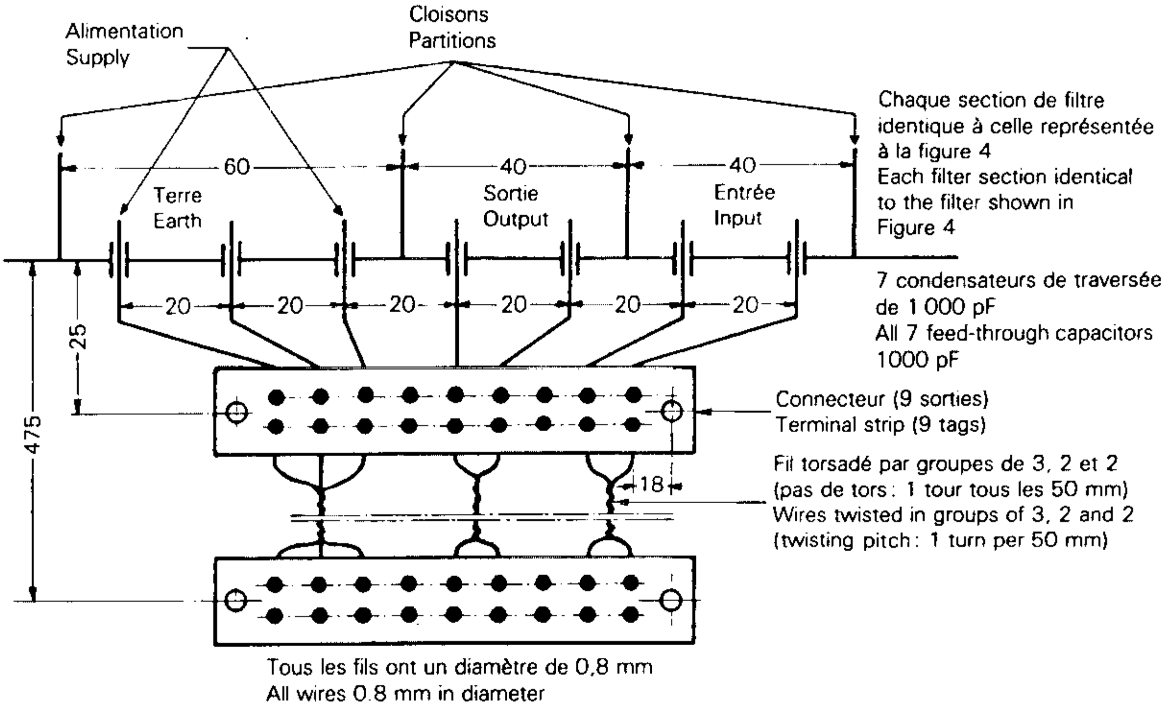


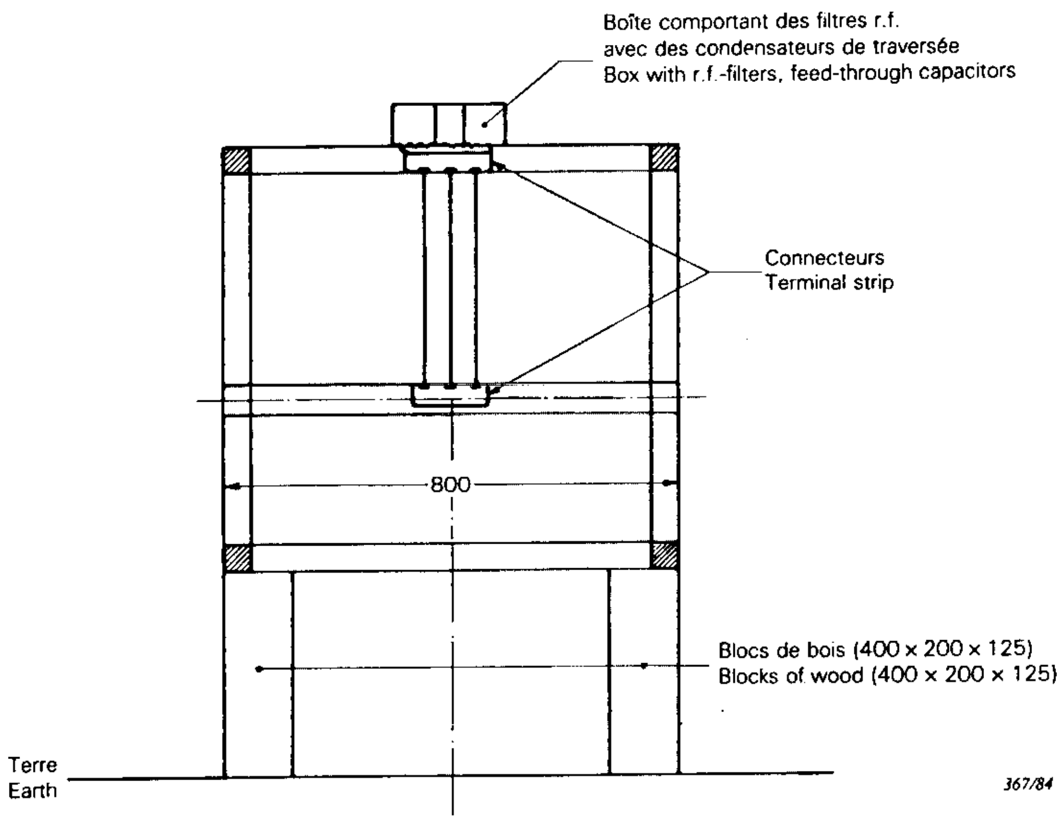
FIG. 3. – Détails des circuits du stripline (toutes les résistances sont en carbone, non inductives (2 W)).
Details of the stripline circuits (all resistors are non-inductive carbon resistors (2 W)).



Dimensions en millimètres *Dimensions in millimetres*

FIG. 4. – Détails des circuits du stripline.
Details of the stripline circuits.





Dimensions en millimètres *Dimensions in millimetres*

FIG. 5. – Détails des circuits du stripline.
Details of the stripline circuits.

APPENDIX A

FIELD INTENSITY AND RADIATED POWER FROM ANTENNAE IN FREE SPACE

A1. Isotropic radiator

The power density S at a point due to the power P_T radiated by an isotropic radiator is given as follows:

$$S = P_T/4\pi d^2 \ (\mathrm{W/m^2})$$

where:

S = power density in watts per square metre
d = distance in metres
P_T = transmitted power in watts

The r.m.s. electric-field strength E in volts per metre and the power density S in watts per square metre at any given point are related by:

$$S = E^2/120\pi$$

where:

120π = impedance of free space.

Accordingly, the field intensity of an isotropic radiator in free space can be expressed as follows:

$$E = \frac{\sqrt{30\,P_T}}{d} = \frac{5.5}{d}\sqrt{P_T}$$

A2. Half-wave dipole

For a half-wave dipole in the direction of maximum radiation:

$$S = 1.64\,P_T/4\pi d^2$$

$$E = (49.2\,P_T)^{1/2}/d = \frac{7.01}{d}\sqrt{P_T}$$

where:

1.64 = maximum gain of a half-wave dipole.

A3. Efficiency of an earthed vertical antenna

The efficiency of an antenna is the ratio of the radiation resistance to the total resistance of the system. The total resistance includes radiation resistance, resistance in conductors and dielectrics, including the resistance of loading coils if used and the resistance of *the earthing system.*

A half-wave antenna operates at very high efficiency because the conductor resistance is negligible compared with the radiation resistance. In the case of the earthed antenna, the earth resistance usually is not negligible, and if the antenna is short, the resistance of the necessary loading coils may become appreciable. To obtain an efficiency comparable with that of a half-wave antenna in an earthed antenna having a height of one-quarter wavelength or less, great care shall be taken to reduce both earth resistance and the resistance of any required loading inductors. Without a fairly elaborate earthing system, the efficiency is not likely to exceed 50% and may be much less, particularly for antenna heights below one-quarter wavelength.

The ideal earthing system for a vertical earthed antenna would consist of about 120 wires, each at least one half wavelength long, extending radially from the base of the antenna and spaced equally around the circumference of a circle. Such a system is the practical equivalent of perfectly conducting earth and has a negligible resistance.

To appreciate the significance of the required earth quality, experimental measurements have shown that for 15 radials, the resistance is such as to decrease the antenna efficiency to about 50%, and for 2 radials, to approximately 25% for a quarter wavelength antenna. *The efficiency is considerably lower with shorter antennae.*

A4. Monopole

The practical "elementary dipole" is a centre-fed antenna having a length that is very short in terms of wavelengths. The current amplitude on such an antenna decreases uniformly from a maximum at the centre to zero at the ends (Figure A1). For the same current I (at the terminals), the (short) practical dipole of length L will radiate only one-quarter as much power as the current element of the same length, which has the current I throughout its entire length. (The field intensities at every point are reduced to one-half and the power density will be reduced to one-quarter.) Therefore, the radiation resistance of a practical short dipole is one-quarter that of the current element of the same length.

The *monopole* of height H (Figure A2) or short vertical antenna, *mounted on a reflecting plane,* produces the same field intensities above the plane as does the dipole of length L = 2 H when both are fed with the same current. However, the short vertical antenna radiates only through the hemispherical surface above the plane, so its radiated power is only one-half that of the corresponding dipole. Therefore, the radiation resistance of the monopole of height H = L/2 is one-half the radiation resistance of the short dipole.

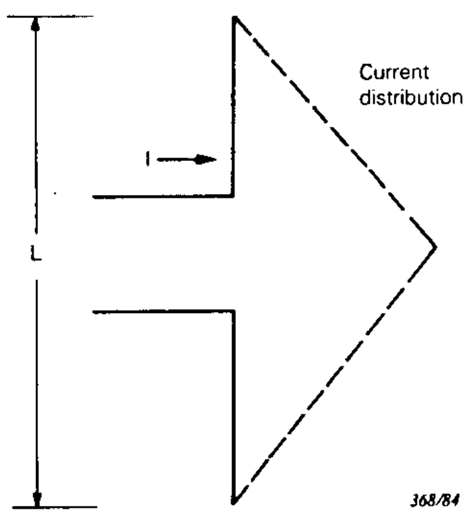


FIGURE A1

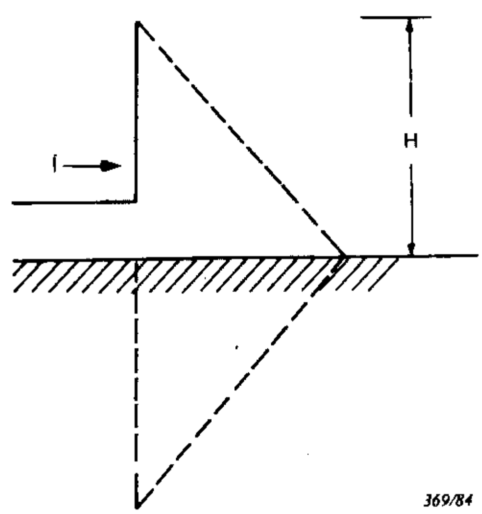


FIGURE A2

The hypothetical current element is a useful tool for theoretical work, but is not a practical antenna.

A5. Portable transceivers (walkie-talkies)

The question regarding what field strengths may be expected from commercial portable transceivers frequently arises. The basis of the question centres around the fact that these communication devices are the dominant radiating interference sources affecting electronic equipment.

The portable transceivers can be treated as a dipole the case of the transceiver being the second limb.

An analysis of measurement conducted by the E.R.A. (Electrical Research Association) and the Research Department of Electricité de France (EdF) on walkie-talkies from six different manufacturers with power ratings ranging from 0.5 W to 12 W at VHF and UHF frequencies reveals a spread of coefficients ranging from $k = 0.45$ to $k = 3.35$ with a mean of $k = 1.6$.

Thus the statistical average can be expressed as:

$$E = \frac{1.6}{d} \sqrt{P} \quad \text{(See Figure A3, page 40)}$$

where:

P = manufacturer's advertised rating of the transceiver, in watts.

Since the experiments (except those performed by E.R.A.) were conducted in a shielded enclosure, it can be assumed that a sufficiently adequate ground plane existed. In actual practice, the portable transceiver is held and keyed by operating personnel. As such, additional losses can be expected.

In the light of the above, the statistical average assumes a more realistic guideline for approximating field strengths.

A6. Near field versus far field (see Figure A4, page 41).

Throughout this discussion the fields we have been discussing are those forming travelling electromagnetic waves that go long distances from the antenna. These are the radiation fields. They are distinguished by the fact that their field strengths are inversely proportional to the distance and that the electric and magnetic components, although perpendicular to each other in the wavefront, are in phase in time. Several wavelengths from the antenna, these are the only fields that need to be considered. Close to the antenna, however, the situation is much more complicated. In an ordinary electric circuit containing inductance or capacitance, the magnetic field is a quarter cycle out of phase (in time) with the electric field. The intensity of these fields decreases in a complex way with distance from the source. These are the induction fields. The induction field exists about an antenna along with the radiation field but dies away much more rapidly as the distance from the antenna is increased. At a distance equal to the wavelength divided by 2π or slightly less than $\lambda/6$, the two types of field have equal intensity. The existence of the near field must be kept in mind when making field-strength measurements about an antenna. Significant errors may occur if the measurement equipment is set up too close to the antenna system.

Additional considerations

The use of transceivers of which the antennae are too close to the electronic equipment is a matter of great importance. Figure A4 can be used as a guideline for approximating the field boundaries. A separation distance of 2 m between the antenna and the electronic equipment is highly recommended. In addition, operation at reduced power ratings will materially reduce the influence of radiated interferences resulting from the use of portable transceivers.

A7. Frequency range

Assignments of frequencies in each country are subject to many special conditions. In addition, specific frequency allocations for the various worldwide regions have been internationally agreed upon. Various services are typically categorized as follows:

- Government
- Public safety
- Industry
- Land transportation
- Domestic, public
- Citizens radio
- Fixed common carrier
- International control
- Television broadcasting
- Frequency-modulation broadcasting
- Television pickup, links, and intercity relay
- F.M. and standard broadcasting links and intercity relay
- Standard broadcasting remote pick-up
- Aeronautical fixed
- Aeronautical, air to ground
- Flight test telemetering
- Aeronautical radio navigation
- Radio navigation and radio location
- Meteorological aids
- Maritime
- Amateur
- Industrial, scientific and medical equipment.

Since the majority of the bands are shared by all of the services, electromagnetic compatibility (E.M.C.) of industrial process measurement and control equipment for one service can readily be extended, with confidence, to all services.

A8. Other test methods

T.E.M. (transverse electromagnetic) cells

At present, T.E.M. cells can only accommodate very small items. A review of available literature indicates that the largest T.E.M. cell on the market can accommodate equipment having a maximum size of 14 cm × 14 cm × 5 cm at 500 MHz. T.E.M. cells are potentially usable for small objects.

Mode-stirred chambers

Standing waves, which are a major limitation in T.E.M. cells, are necessary to the operation of mode-stirred chambers. At this time, however, these chambers are in the development state and not generally available.

Open antenna ranges

This method is appealing in less populated sections of the country. In densely populated sections, legal limits prohibit the transmission of the required field strengths. The precision of measurements is substantially increased due to the absence of reflected waves.

A9. Selection of the severity levels

The test severity levels shall be selected in accordance with the electromagnetic radiation environment to which the E.U.T. may be exposed when finally installed.

The following classes are related to the levels listed in Clause 5: Severity levels; they are considered as general guidelines for the selection of the appropriate levels:

Class 1: Low level electromagnetic radiation environment, such as levels typical of local radio/television stations located at more than 1 km and levels typical of low power transceivers.

Class 2: Moderate electromagnetic radiation environments, such as portable transceivers that can be relatively close to the equipment but not closer than 1 m.

Class 3: Severe electromagnetic radiation environments, such as levels typical of high power transceivers in close proximity to the control equipment.

Class 4: Open class for situations involving very severe electromagnetic radiation environments. The level is subject to negotiation between the user and manufacturer or as defined by the manufacturer.

$$E = \frac{1,6}{d}\sqrt{P}$$

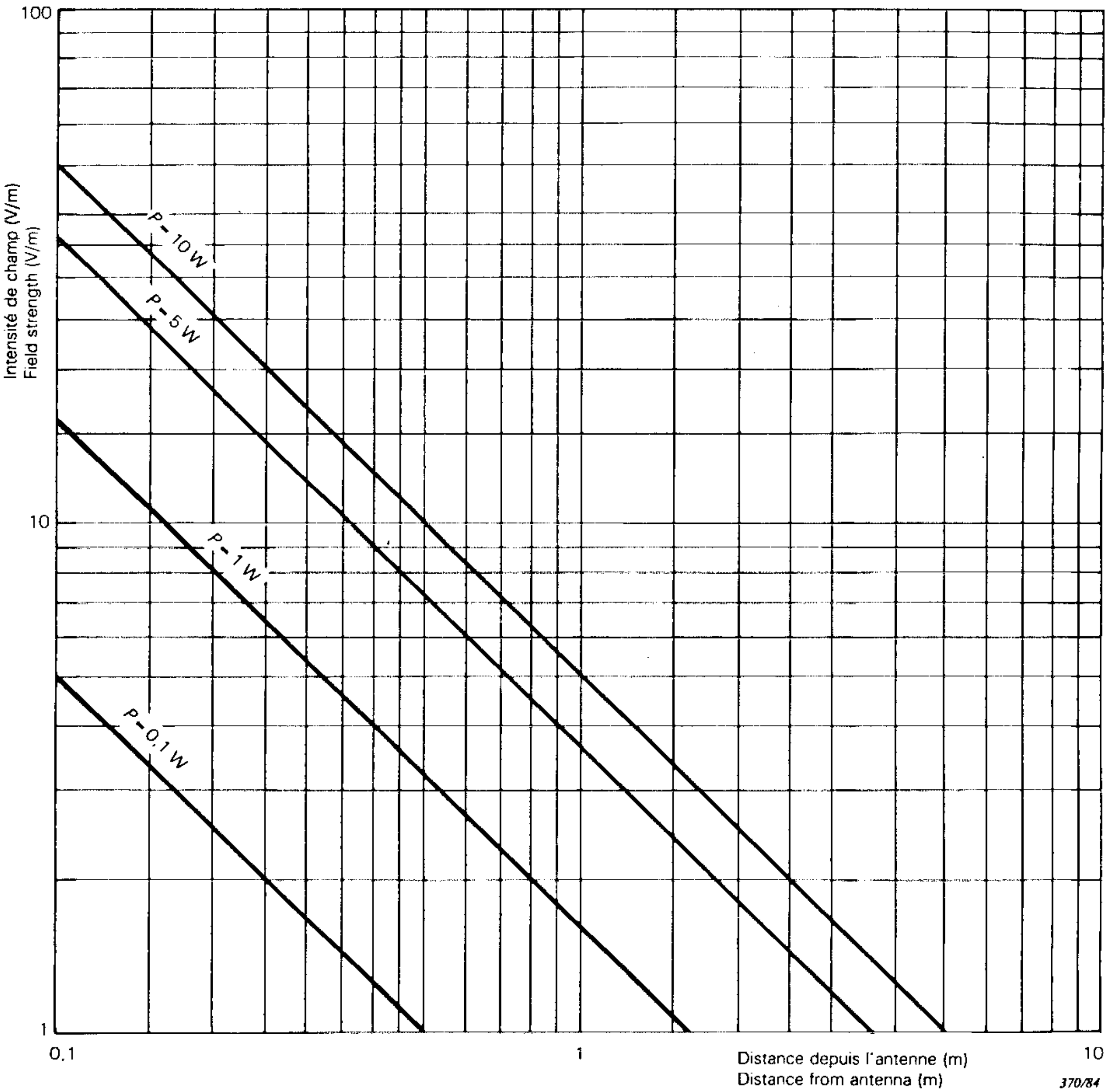


FIG. A3. – Intensité de champ approché pour une antenne unipolaire non reliée à la terre (walkie-talkie) en champ lointain ($d \geqslant \lambda/2\pi$).
P = puissance assignée du walkie-talkie.
Approximate field strength for a non-earthed monopole (walkie-talkie) in the far field ($d \geqslant \lambda/2\pi$).
P = walkie-talkie rating.

$$d = \frac{\lambda}{2\pi}$$

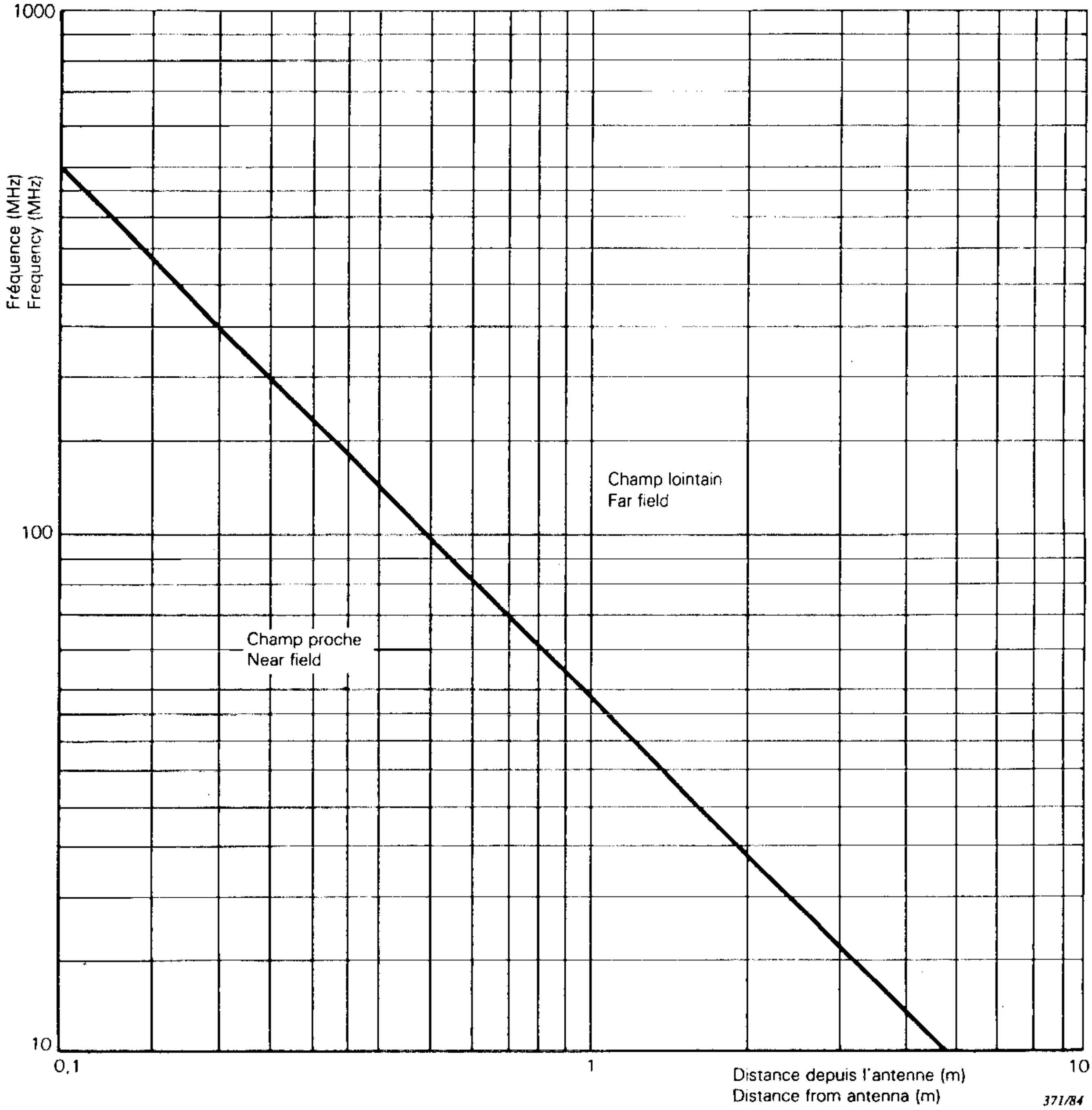


FIG. A4. – Relation champ proche/champ lointain.
Near/far field relationship.