REPORT 778-2

WIRELESS COMMUNICATION SYSTEMS FOR PERSONS WITH IMPAIRED HEARING

(Question 49/8)

(1978-1982-1990)

1. Introduction

Many forms of hearing impairment cannot be satisfactorily improved by the provision of amplification only. Difficulties such as distortion in the residual hearing, loss of binaural directivity, emphasis of environmental noise and room reverberation lead to the use of systems incorporating the placement of the microphone near to the speaker rather than to the listener.

2. Transmission systems

A number of means have been used to transfer the speech signals from the microphone to the listener's hearing device. The means include infra-red radiation, the magnetic induction field internal to current loops, VHF radio and the external induction field of a radiating antenna.

The use of infra-red radiation is of particular interest as it does not occupy allocated radio spectrum.

The radio induction field system is of particular interest as its realization leads to the following advantages:

- efficient use of the radio spectrum;
- ease of incorporation, with an acoustic hearing aid, into a single device;
- simulation of normal conditions of hearing;
- satisfactory use within the school, home, industrial or external environment.

On the other hand, VHF systems are employed to take advantage of the following:

- large coverage areas;
- relative immunity to natural and man-made noise.

3. System concepts

3.1 *Radio induction field system*

The mobile-to-mobile induction-field hearing assistance system exploits the FM capture effect to permit co-channel operation with selection by proximity. This pattern of selection closely parallels that used in ordinary conversation.

When an induction-field wireless hearing aid receiver is operated in the vicinity of two co-channel transmitters using a medium deviation FM transmission, the rapid change in field strength together with the FM capture effect ensures that there is a rapid changeover in reception from the more distant transmitter to the nearer transmitter with little subsequent breakthrough of consequence. For example, for a frequency deviation of 12 kHz and 75 μs receiver de-emphasis, as reported for the Australian system in Annex I, it can be shown that, at a field strength ratio of 8 : 1, the maximum breakthrough from the more distant transmitter is 34 dB (unweighted). Within the region of inverse cubic decay of the induction field, the unwanted transmitter need only be at twice the distance of the wanted one to achieve this result. The field decay rate is illustrated in Fig. 1.

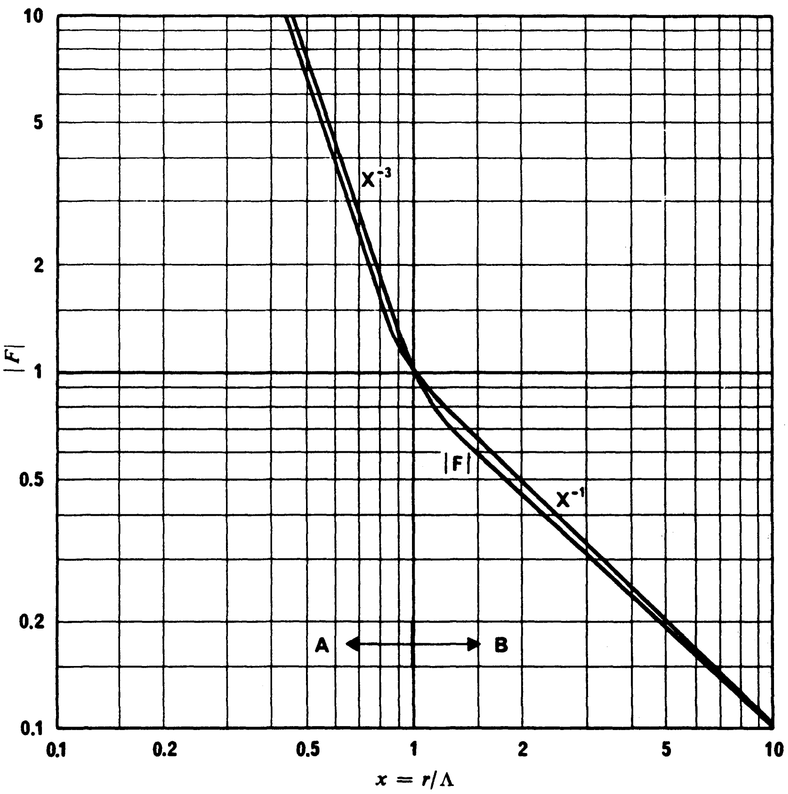

FIGURE 1 — *The field in free-space near a small dipole*

The field intensity $|F|$ in the equatorial plane is proportional to

$$|1/r^3 + j/\Lambda r^2 - 1/\Lambda r^3|.$$

Λ is the radian wavelength $= \lambda/2\pi \approx$ 48 metres divided by frequency in MHz

A: Induction
B: Radiation

A magnetic induction field is preferred as it is less perturbed by conducting objects such as the human body, and is compatible with the use of compact ferrite rod antennas. The measured decay of a magnetic induction field is shown in Fig. 2.

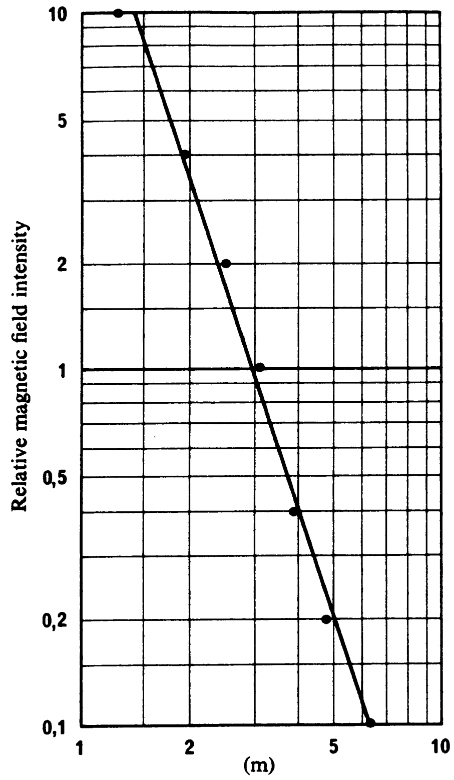

FIGURE 2 — *The measured decay of a magnetic induction field*

The points represent the measured values of the field; the straight line is an exact inverse cubic decay. The measurement were made in the laboratory in proximity to large metal objects. A frequency of 3.6 MHz was used.

The design of the induction-field wireless hearing aid proceeds from the following four principles:

– The upper limit for the carrier frequency is about 4 MHz; at higher frequencies the extent of the rapidly decaying induction field is less than 12 m, which is insufficient.

– The lower limit to the maximum frequency deviation is taken as 12 kHz as with lesser deviations, excessive breakthrough from nearby co-channel transmission occurs.

– The lower limit of the carrier frequency is taken as 3 MHz. The quality factor (Q) of tuned windings on ferrite rod antennas is of the order of 200. At lower carrier frequencies the bandwidth of the tuned antenna circuits cannot accommodate the required frequency deviation.

– The mean carrier frequency of all transmitters should be stabilized to within 20 Hz of their nominal channel frequency to avoid the production of sustained audible beat notes in receivers operated near more than one co-channel transmitter. Since the carrier frequency has been set below 4 MHz, the required degree of stabilization can be obtained by reference against quartz crystal oscillators operating at ambient temperature.

3.2 *VHF system*

Systems employing VHF radio transmission are capable of providing communication over distances greater than those using the radio-induction field system, as they employ transmission via a radiation field which decays less rapidly with distance than does an induction field. As a consequence, VHF radio transmission systems require that each transmission in any locale, such as a school and its environs, be assigned a separate frequency channel. This requirement is met with available frequency assignment methods, and is not a significant factor in the operation of the system.

VHF reception is generally less susceptible to interference from natural and man-made noise than is reception at lower frequencies, and systems employing VHF radio transmission may be useful in certain circumstances to avoid local problems of interference which may affect the operation of the radio-induction field system.

Radiocommunication systems intended only for short-range communication are capable of producing high field strengths at their required working distances, without radiating significant levels of power. Exploitation of the resulting possibilities of shared spectrum usage results in improved spectrum utilization, and may allow large numbers of channels to be made available to satisfy the requirements of large schools for children with impaired hearing.

The requirements of VHF auditory training systems used in the United States of America [CCIR, 1978-82] are also shown in Annex I.

ANNEX I

SYSTEM CHARACTERISTICS

1. Radio induction field system used in Australia

Using the system design principles described in the body of this Report, an operational induction-field wireless hearing aid system has been developed and is now in widespread use in Australia.

Evaluation of the system has indicated it provides substantial benefits including:

- greatly improved speech discrimination in noisy environments;
- virtual elimination of the problems of co-channel interference from adjacent systems as a result of the FM capture effect;
- greater flexibility for educational use. For example, with careful placement of pupils, a single frequency can be used in open plan classrooms with more than one teacher;
- the number of channels required in locations where there are many groups of users is reduced to four. Four channel transmitters and receivers have been developed for this purpose which also:
  - simplify frequency changes;
  - enable children to use the devices in different classrooms by selecting the appropriate frequency;
  - overcome difficulties associated with mixing groups of children with devices operating on different frequencies.

Some interference to reception has been experienced on the 3 175 kHz frequency (the frequency of the single channel devices) from high powered (10 kW) transmitters operating on 3 184 kHz at distances up to 30 km. This has been resolved by using four channel devices on other frequencies and in one case by changing the frequency of the high powered transmitter.

There has also been interference to the reception of signals on 3 175 kHz from the seventh harmonic of intermediate frequency (7 x 455 kHz = 3 185 kHz). This spurious signal is generated within the receiver and degrades the quality of the received signal to noise ratio by adding to the receiver noise level. The problem has been overcome by altering the circuit board layout to minimize the interaction between the radio frequency and audio frequency signals.

The parameters are as follows:

Transmission medium:	Magnetic dipole induction field
Modulation:	FM
Frequency deviation:	± 12.5 kHz
Carrier frequencies:	3 175, 3 225, 3 275, 3 325 kHz
Frequency tolerance:	± 20 Hz
Audio frequency range:	100 Hz - 5 kHz
Audio pre-emphasis:	6 dB/octave
Transmitting antenna:	Ferrite rod, 127 mm x 10 mm, disposed vertically
Transmitter final stage power:	60 mW
Field strength produced at 3 metres:	11 mV/m (measured at a frequency of 3 175 kHz)
Transmitter radiated power:	38 nW (calculated from above)
Transmitter spurious emission:	Undetectable, but calculated as 0.1 pW
Transmitter dimensions:	145 mm x 53 mm x 18.5 mm
Receiving antenna:	Ferrite rod, 57 mm x 10 mm, disposed vertically
Receiver type:	Single conversion superheterodyne
Receiver dimensions:	80 mm x 53 mm x 18.5 mm (four channel device) 70 mm x 53 mm x 18.5 mm (single channel device)
Intermediate frequency:	455 kHz
System range:	12 m (subject to environment)

The low carrier frequency, which is specified to ensure that transmission takes place via an induction field, confers other benefits. It assists in keeping the receivers' battery consumption low and allows good image rejection to be obtained without recourse to double conversion superheterodyne techniques.

The use of a self-contained ferrite rod antenna is particularly convenient in a transmitter designed to be handed informally to another person.

2. VHF radio systems used in the United States of America

Systems have successfully shared the 72-76 MHz and the 88-108 MHz frequency bands for many years, with the type of radio services to which these frequency bands are allocated by the Radio Regulations.

2.1 *72 to 76 MHz*

Channel bandwidth:	50 kHz for a narrowband device 200 kHz for a wideband device
Frequency tolerance:	± 0.005% (Transmitter)
Frequency stability:	± 0.005% (Receiver)
Field strength produced at 30 m:	Not to exceed 8000 µV/m
Transmitter radiated power:	1170 µW (calculated from above)
Modulation requirements for FM:	± 20 kHz maximum (narrowband) ± 75 kHz maximum (wideband)
Out of band emissions:	25 kHz or more from carrier, no more than 150 µV/m at 30 m for narrowband. 150 kHz or more from carrier, no more than 150 µV/m at 30 m for wideband.
Receiver selectivity:	40 dB minimum, adjacent channel
Receiver image rejection:	40 dB minimum.

2.2 *88 to 108 MHz*

Channel bandwidth:	200 kHz
Field strength produced at 15 m:	Not to exceed 50 µV/m
Transmitter radiated power:	0.011 µW (calculated from above)
Out of band emissions:	100 kHz or more from the carrier, no more than 40 µV/m at 3 m
Receiver standards:	Comply with normal receiver standards for this band.

REFERENCES

CCIR Documents

[1978-82]: 8/88 (USA).

BIBLIOGRAPHY

BURGESS, V., CHRISTEN, R., DONALD, G. and LOWE, A. [February-March, 1979] Radio frequency hearing aids. The need for complementary and compatible channel allocation. *The Volta Rev.*, Vol. 81, **2**, 91-99.