Radiating cables in buildings and city streets

An investigation of radiating properties for localized radio coverage

by R. Johannessen & P. K. Blair

Standard Telecommunication Laboratories

With the growing needs for radio-communication, radiating cables are finding increased acceptance in many different areas as a convenient interface between radio base stations and space. The usefulness lies in the degree of control of the coverage given to the designer in that good radio communication is achieved between a base station and mobiles in the vicinity of the cable whereas other localities have a restricted field strength. Thus by using radiating cables and locating them where communication is desired, the frequency spectrum pollution is greatly reduced compared to the case when conventional antennas are employed at the base station.

This article describes two uses of radiating cables in which this feature is important. The first is in an indoor application where the object is to achieve good communication within a building coupled with minimal external leakage. In the second case, a possible use for such cables in city streets is considered.

Indoor application

In order to obtain a qualitative idea of the performance of such installations, extensive measurements have been carried out at the building complex belonging to STL in Harlow and it is these measurements which are reported on in this section.

The laboratories are located in flat countryside immediately east of the A11 Harlow bypass. Between the A11 and the laboratories is a cluster of trees. Towards the south and east of the laboratories the aspect is generally open. Fig.1 shows a plan view of the layout of the buildings. Each building is known by a reference letter shown in Fig.1, thus the four buildings facing south are known as U,S,E and D.

The main features of the site are as follows:-

Four similar blocks U,S,E and D are set out in a straight line, each block having two floors. At the east end is C block having four floors. These five blocks are characterized by having a central corridor with laboratories and offices on both sides. Corridor and labs are separated by walls which, over 90% of their height, have a solid metal construction, the upper 10% being glass. Z block has a metal/glass wall running east west such that the northern part of the building — about ¼ of total floor area — is offices, the rest being laboratory in generally open plan arrangement. The north and south walls of blocks U, S, E, D and Z plus the east wall of block C are about 50% glass.

Three cables are located in the laboratories. They all start between D and E blocks. One cable runs through E,

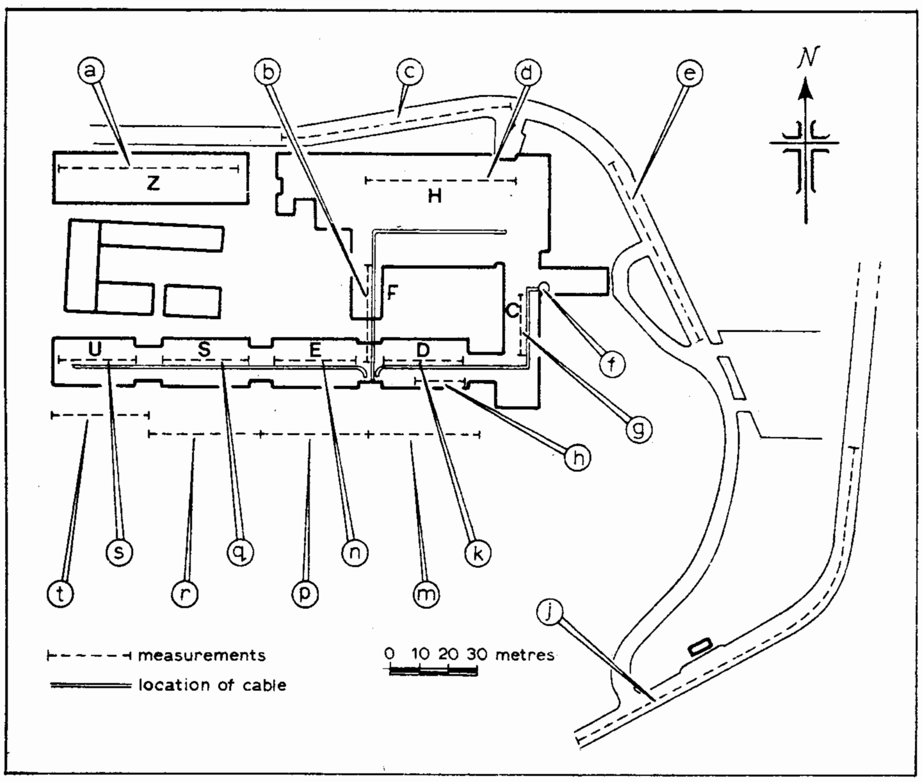


Fig. 1. Layout of building complex and summary of results.

Table 1

Reference in Fig. 1	Floor level	Coupling	Standard devn.
a	2	109	3.4
	1	129	5.6
b	2	66	4.1
	1	56	4.9
c	1	116	3.6
d	1	93	4.1
e	1	114	5.1
f	X	87	6.4
g	4	87	4.7
	3	79	4.6
	2	71	3.3
	1	58	5.4
h	1	79	5.7
j	1	110	6.0
k	2	66	3.2
	1	49	4.8
m	1	87	3.9
n	2	52	4.0
	1	44	3.6
p	1	85	2.8
q	2	60	3.6
	1	47	3.8
r	1	89	3.5
s	2	78	4.4
	1	54	3.4
t	1	96	3.6

S and U blocks between ground floor and the 1st floor. The second cable runs along D and C block between ground and 1st floor level and then runs up the elevator shaft at the end of C block. The third cable runs along F and H blocks between ground and 1st floor. A cross section of buildings U, S, E, D would show that the cable is positioned above the ground floor suspended ceiling. Thus between the cable in S block and the front of the building is first the metal/glass wall and then the outside wall.

The cables used were all of the long continuous slot type with an opening of 180°. The nominal coupling of the cable at 450MHz is 60-70dB for a range from the cable axes of 1 to 5 metres and the insertion loss is in the region of 73dB/km at the same frequency. Both coupling and insertion loss are the values measured with the cable in a nominal free space environment.

The three cables were connected together so that a reasonable impedance match existed. The combined cables were energised at 454MHz (u.h.f. band) using a Starphone mobile radio transmitter thoroughly screened.

The signal levels at different points inside and outside the buildings were measured by a series of runs. Each run is shown in Fig.1 as a broken line along which a receiver was moved. For each such run some 100-200 spot measurements were taken of the received signal level from a vertical $\lambda/4$ dipole connected to the receiver. The results for each run are shown in Table 1. The first number for each run is the floor number such that 1 represents the ground floor. The second figure is the difference in dB between the signal power received and that flowing out of the transmitter. The mean value for the run is the one recorded. The third figure is the standard deviation for all the measurements for that run.

Results commentary

Note that the signal level drops as one moves along the cable from block E through block S and to block U. Similarly from block D to block C. This is mainly due to the insertion loss of the cable. Also the signal level is strongest on the ground floor and weaker one floor up. This is due to there being thin false ceiling tiles between ground floor and the cable, whereas between cable and the top floor is a layer of concrete which attenuates the signal. In the case of C block the two upper floors are in general far from the cable. The signal level there is due partly to that picked up from C block ground floor, partly from the lift shaft of C block and partly from the cable running into F block. In the case of Z block the signal level on the top floor is stronger than on the ground floor. This is probably due to the shadowing casued by the low buildings positioned between U block and Z block.

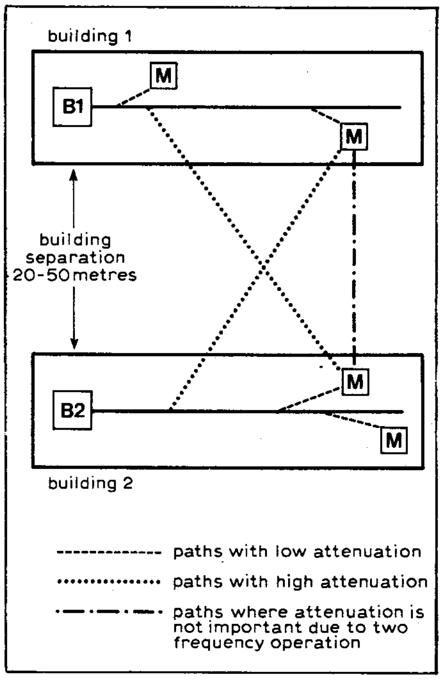


Fig. 2. Mechanism of co-channel working. "M" indicates mobiles.

A very large difference is noted between ground floor of F block and ground floor H block. This is due to two factors; first, measurements in H block had to be carried out much further from the cable than was possible in F block and second, a solid brick wall was positioned between the cable position in H block and the place of the measurement. Along the front of the building it will be noted that there is in the order of 40dB difference between outside measurements and those on the ground floor immediately under the cable. The signal level on the surrounding roads has in all cases a mean value at least 100dB below the level fed into the cable.

It will also be noted that the coupling on the ground floor in buildings U, S, E D, C and F is closer than the nominal coupling for the cable. This is probably due to the cable coupling into pipes and other cables located in the same ceiling ducting as is the radiating cable.

Fig. 2 indicates how it is now possible for mobiles in building 1 to talk to base station B1 via its cable, while the mobiles in building 2 talk on the same frequency to base station B2 via its cable.

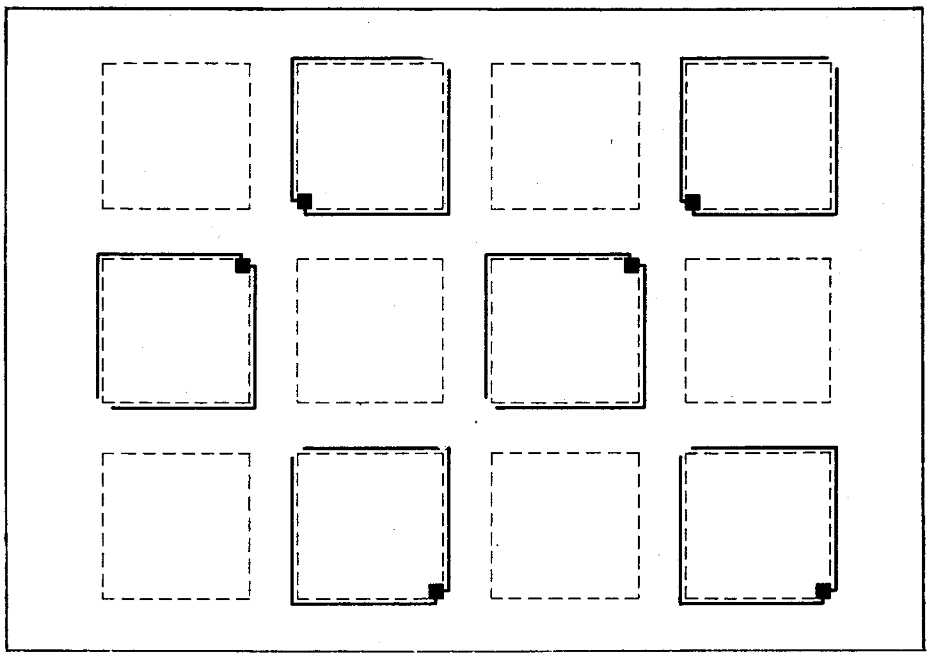
An indication of the degree of protection between two buildings can be given by considering Z block compared to S block. In Z block upstairs the received signal level to 95% probability is $109-1.96\times3.4$ which is 102.3dB below transmitted signal level. In S block upstairs the 95% probability for wanted signal is $60\times1.96\times3.6$ which is 67.1dB below transmitted signal or a difference of 35.2dB from that in Z bloc.

Cables for city streets

Commenting on the increasing demand for radio spectrum, paralleled by the population explosion, Hardeman[1] says that in the US, pockets of excessive crowding occur in just about all bands under 10GHz and new technology is one of the means required to relieve the pressure. Land mobile users in the US have saturated the v.h.f. and u.h.f. bands and are now searching for the most efficient methods to apportion a new band at 900MHz. Japan has an equal problem both at 150 and 460MHz and Linney[2] has outlined the steps the UK Post Office are taking to meet the growing demand for their Radiophone service. The problem is the same – where to find frequencies to satisfy a growing number of users.

An approach which has been proposed for use in the US cities is the cellular approach[1,3] which takes advan-

Fig. 3. Arrangement of radiating cables in small cell system.



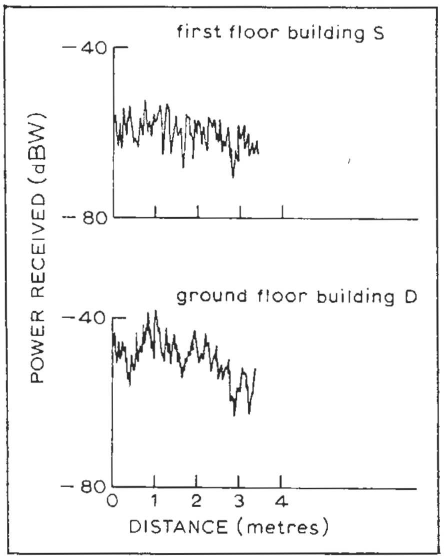
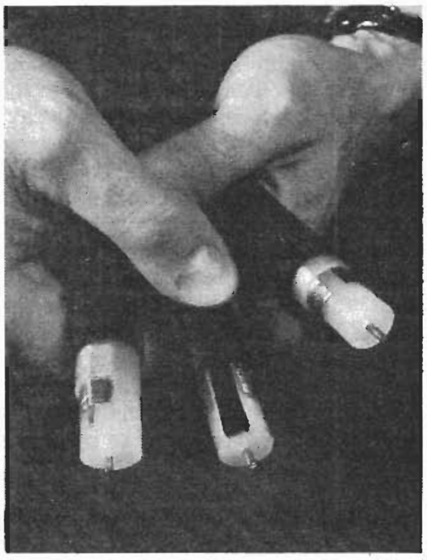
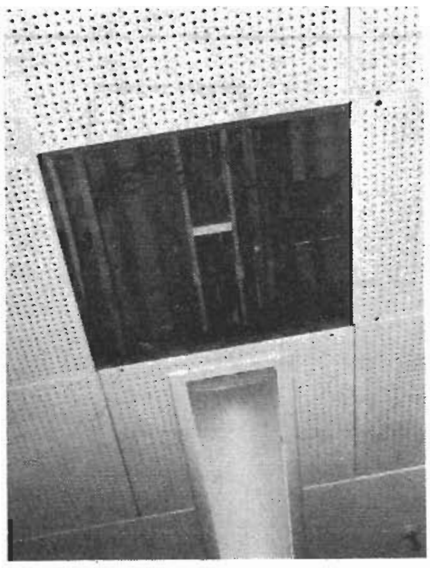


Fig. 4. Signal level variations measured in buildings S and D. The power received (vertical scale) is at the terminals of λ/2 dipole for 1W into the cable system.



Three types of radiating cable made by STC Cable Division.



Ceiling of E1 showing how the cable is laid without any complicated fixings and next to a variety of other pipes and cables.

tage of the large geographical distances between co-channel mobiles. It is claimed that potentially, the cellular approach requires much less spectrum to provide a given quality of service to the user. The size of the cells determines how efficiently the radio spectrum is used — the smaller the cells the more times the frequency can be repeated without mutual interference between users. But the smaller the cell, the more complicated and costly must be the organization of the system including position finding of the mobile, assigning of frequency and switching of frequency as the mobile moves from one to a neighbouring cell.

Cables for the cell

One problem with the cellular approach is the extent to which a message to/from one cell spills into a neighbouring cell. This is aggravated by the need to overcome building shadowing with higher transmitter power than that required for free space propagation. Thus in order to have sufficient signal strength in all streets within one cell, there is likely to be excessive signal strength in some parts of the neighbouring cells.

Radiating cables appear to offer a natural solution to this since the signal level drops off rapidly as one moves beyond the cable ends[6]. Furthermore if the radiating cables are located along the streets, effectively distributing the antenna where coverage is desired, there will only be minimal shadowing by the buildings.

In Fig. 3 a possible approach is shown in a city where the streets can form a regular pattern. The broken lines represent the building outlines. The shaded blocks are transceivers connected to one or more radiating cables. The adoption of centre or end feeding for the cable will depend upon building geometry and frequency used. Assuming the base of a building is 100 metres square and an end fed arrangement is used, the cable would be around 400 metres long corresponding to an insertion loss of typically 12dB at 160MHz or 33dB at 900MHz.

An audio connection will be required between the transceivers working the cables and a central exchange. Possibly ordinary telephone line could fulfil this function.

Assuming the radiating cables are located on the external walls of buildings one can expect a coupling loss of about 90dB. The precise loss is a function of cable type, fixing method employed and the degree to which the surroundings re-radiate. Four hundred metres of cable operating at 160MHz can be expected to have an insertion loss of about 12dB. Man made interference levels in urban areas are known to be high; however, it will be recalled that whereas the insertion loss of a cable increases with increasing frequency, the ignition interference level falls. Walker[4] suggests a drop in interference level of 20dB when the frequency is increased from 150MHz to 900MHz.

Vehicle location

Common to all small cell systems is the need for vehicle location and following. The control system must know where a vehicle is and as it moves towards the boundary with another cell another frequency must be in readiness or the same frequency in the neighbouring cell must be cleared. The smaller each cell is, the greater becomes the requirement for vehicle following; thus more rearrangement of channels may become necessary during one particular radio-call. McClure[5] has outlined some of the control functions and formats which could be used in a free radiating small cell system. The radiating cable provides a medium for position location and a variety of methods could be considered as candidates for study.

It will be appreciated that there are very many further aspects to this proposed scheme which require further study and careful analysis. For example, the interface and interaction with the telephone switching system, the channelization scheme and associated controls, position finding methods for operation with radiating cable systems, the integration of the system with other "free radio" schemes and, last but not least, its cost effectiveness.

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REFERENCES

1. Hardeman, L. J., 'Heavy Traffic Calls for Crowd Control in the Electromagnetic Spectrum', *Electronics International,* September 25, 1972, pp.83-98.
2. Linney, P. J., 'An improved radiophone service for London', The Post Office Electrical Journal, July 1972, pp.98-102.
3. Frenkiel, R. H., 'A High-Capacity Mobile Radio-Telephone System using a co-ordinated Small Zone Approach', *IEEE Trans. Vehicular Technology,* May 1970, pp. 173-177.
4. Walker, B., 'The advantages of UHF', *Communication,* July 1969, p.27.
5. McClure, G. F., 'Compatibility of Small Cell Mobile Telephone Systems', *Telephone Engineer & Management,* February 1, 1973, pp.40-44.
6. Fernandes, A. S. C., Harms, P. L., and Johannessen, R., 'Some Engineering considerations affecting the use of radiating cables in communications between vehicles and traffic control centres', Leaky feeder communication systems colloquium, University of Surrey, April 1974.