

REPORT 902-1

LEAKY-FEEDER SYSTEMS IN THE LAND MOBILE SERVICE

(Question 36/8)

(1982-1990)

1. Introduction

Leaky feeders are also referred to sometimes as 'radiating cables' but this term is inaccurate and should be avoided. The alternative expression 'leaky cable' is acceptable in specific regard to the feeders themselves, rather than the system, in the vast majority of cases where the feeder does in fact take the form of a cable rather than an open-wire transmission line.

A leaky feeder is a form of transmission line that enables radio communication to take place with or between mobile sets in its vicinity through its leakage fields, while substantially providing the linear range of the system through its internal propagation properties (Delogne, 1982; Martin, 1982).

Such systems are used in confined spaces, such as tunnels, mines or large buildings, where natural propagation is inadequate. They may be completely self-contained or extensions of conventional surface systems otherwise using free radiation: in the latter case the feeds for the underground coverage may either be taken 'off air' or share a base station with the surface antenna directly. Conversely, a primarily underground system may interface with a surface antenna to provide local cover, for example, of the precincts of a mine.

Leaky feeders may also be used on the surface, to confine radio coverage and thus improve spectrum efficiency.

The term 'leaky feeder' can also be taken to include a non-leaky cable with periodic discrete radiators or mode converters (Delogne and Liegeois, 1971).

2. Classification of leaky feeders

The following types of leaky feeder are commonly used:

- (a) bifilar lines;
- (b) continuously leaky coaxial cables;
- (c) coaxial cables with periodic apertures;
- (d) cables with mode converters.

Types (a) and (b) are intrinsically non-radiating in the sense that a cable of infinite length extending in free space can only carry waves guided by the structure. However, any discontinuity along the cable causes mode conversion and radiation.

In type (c), the periodic apertures are radiating discontinuities and act like elements of an antenna array. Maximum radiation is obtained in oblique directions determined basically by the ratio of the spatial interval to the wavelength.

In type (d) the mode converters or radiating elements are separate discontinuities acting in isolation.

2.1 Basic performance parameters

The performance of a leaky feeder system may be characterized by two parameters:

- longitudinal attenuation,
- coupling loss.

The longitudinal attenuation is governed primarily by the factors which apply to normal transmission lines, such as construction, conductor size and dielectric. Additionally there is a small loss component attributable to the leakage (or mode converters).

The coupling loss is, in general terms, the power loss between the feeder and a mobile antenna in its vicinity. For the commonly used coaxial types of leaky cable it is dependent on the degree of shielding in the feeder construction, the configuration of the shield or conductors and the permittivity of the dielectric. For a given cable construction it should also be noted that the coupling loss is also dependent upon:

- the environment in which the cable is mounted;
- the cable mounting position;
- the characteristics, position and orientation of the mobile antenna;
- the operating frequency.

The longitudinal attenuation of cables designed for a low coupling loss can increase substantially with close mounting of the cable to a wall, structure or other cables or with surface contamination, except for cables specifically designed to minimize this effect such as the triaxial (tri-coaxial) cables and inherently non-leaky cables using discrete mode converters. In the same process as the increase in attenuation the coupling loss is usually decreased (i.e. the received signal is increased locally).

For a given coupling loss, various types of cable are not necessarily subject to the same increase in attenuation by these effects of proximity and contamination. Bifilar lines are by far the most sensitive, followed by longitudinally slotted cables and lastly by the various types of cable with numerous small holes. Some braided types of cable are so insensitive to proximity effects that they may be run in normal hangers along with power cables, telephone lines and other such conductors without undue degradation of their performance in the VHF range.

2.2 Bifilar lines

Bifilar lines (nominally balanced) in general have a low coupling loss and a lower longitudinal attenuation for a given conductor size in comparison with coaxial cables. For these reasons they have generally the lowest cost of all leaky cables. However, they can be sensitive to mounting position and surface contamination at VHF and more especially at UHF.

If a bifilar cable is given a tight twist (e.g. several turns per wavelength) the balance is normally improved against proximity effects, thereby improving the longitudinal propagation, but in the same process the coupling loss may be increased by up to 15 dB (Martin, 1975).

2.3 Coaxial cables

2.3.1 Continuously leaky coaxial cables

This type (with either two or three coaxial conductors) includes the loosely braided cables, cables with continuous slots and cables with discrete apertures or slots separated by distances much smaller than the wavelength.

Since these coaxial cables have an imperfect outer conductor, part of the transmission-line energy travels outside the cable as a leakage field [Delogne and Safak, 1975; Fernandes, 1979].

Basic cable properties that (together with environmental factors) determine the coupling loss are (a) the internal propagation velocity and (b) the surface transfer impedance of the outer conductor. It is preferable to characterize cables by quoting these quantities, which can be measured in the laboratory, rather than an arbitrarily and artificially defined 'coupling loss'. Propagation velocity is determined by the internal dielectric constant, while surface transfer impedance is determined by the structure of the outer conductor and is increased, for example, by increasing the size or number of apertures.

Increase of surface transfer impedance results in a proportional increase in the coupled signal, and is normally accompanied also by an increase in longitudinal attenuation depending on the precise cable structure. The sensitivity of the longitudinal attenuation to mounting position also becomes more marked, but there is evidence that this is more a function of 'hole size' than of surface transfer impedance in itself, and so a large number of smaller holes is better than fewer large holes in this respect.

Increase of internal cable velocity (e.g. through the internal dielectric constant) increases the total energy in the leakage field, though this relationship is not linear and involves other parameters. The field close to the cable is actually reduced, but the spread of the field increases. The congestion radius, within which most of the power of the coaxial-mode leakage field is contained, is of the order of 60 cm at 100 MHz and varies in inverse ratio to the dielectric constant of the internal cable insulation. It is also directly proportional to wavelength.

The mechanism by which a mobile antenna outside the congestion radius is coupled to the coaxial mode is the diffraction of the coaxial-mode leakage fields by the inhomogeneities within the congestion radius; these are the inhomogeneities and irregularities in the environment, cable construction and suspension brackets and obstacles of all kinds. This diffraction is a random process: furthermore, in tunnels the resulting coupling loss does not significantly depend on the distance of the antenna from the cable; this is because the diffracted fields are carried by numerous waveguide modes.

2.3.2 Coaxial cables with periodic apertures

Coaxial cables having discrete apertures with dimensions and/or periodicity comparable with the wavelength are a source of radiation.

A coaxial cable with zig-zag slot arrays can be treated as an antenna array [Nakahara and Kurouchi, 1968] and the transmitted energy in the cable is little affected by the radiation from the slots. The radiating field propagates as a cylindrical wave.