COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Reprint from the proceedings of the ITC Conference Basel, November 1994

RFS kabelmetal
H.-D. Hettstedt, B. Herbig, G. Klauke, R. Nagel

RFS Connect with the best®
COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

1. ABSTRACT

This contribution deals with the results of a measurement campaign in which the influences of a tunnel on the electrical characteristics of Leaky Feeders were investigated. Four different types were tested, two broadband cables working in the coupling mode from 30 to 2000 MHz, and two cables working in the radiating mode up to 900 MHz.

2. INTRODUCTION

Leaky Feeders have already been in use for some time in multiband systems in tunnels and other confined areas under various conditions. Mostly they are in competition with narrow banded antenna solutions under the aspect of costs. In train and metro tunnels, cables seem to be the only solution because of the masking effects of the trains.

Though a long tradition of successful applications of Leaky Feeders can be demonstrated by very positive experiences under very different and sometimes extreme conditions, often a very diverse opinion on confidence in Leaky Feeders is met among system engineers. One of the reasons may be related to the situation that technical specifications, especially data of coupling loss, have been gained under very different conditions, thus the specs could not be compared directly.

In recent years, an international standardisation on measurement procedures has been achieved, [1]. Thus coupling loss figures, the most critical parameter, have become reproducible from supplier to supplier. However, these specs are derived from measurements on testranges in the free space, and one of the oldest questions remains: how do these specs represent the performance of Leaky Feeders in confined areas?

Our experiences has been that most of the complaints have been resulted from incorrect installation or failing to use the recommended accessories. Intensive investigations on environmental tests confirmed the rule that the greater the proportion of uncovered sections in the outer conductor, the higher the sensitivity of the Feeders is to humidity. Thus it was conclusively shown that continuously slotted cables show an extremely high sensitivity, and that RLF-type cables are virtually unaffected. These new tests and test procedures and longterm applications have led to a position where it is possible to find the proper type of Feeder for the actual purpose and to make a relatively secure prediction of performance even under extreme conditions.

At least some of the important questions remain. The first one is, how to qualify and quantify influences of a tunnel on the electrical characteristics. Another question is, are the influences on cables in the radiating mode higher than on those in the coupling mode. This could lead to the understanding that the newer cables in the radiating mode lose their regular field characteristics of the open air and of course their importance, [2]. This paper shall help to clarify the situation, but cannot give universal explanations, because only one type of tunnel was investigated.
3. MEASUREMENTS

3.1 Tunnel

In Hanover a metro tunnel has been available for an intensive measurement campaign. At the Waterloo Station one line is not used, thus two closed tunnel sections can be reached via the platform. Fig. 3.1 shows one of two test areas at a maximum length of approximately 130 m each in the tunnel end sections. Fortunately no gravel and rails obstructed the measurements. The tunnel has a rectangular size which differs in height and width, presenting the opportunity to investigate different tunnel types. Only the last part of the sections shows a constant size. The walls are of smooth concrete, the area dry, but very dusty.

The cables were installed using special clamps on the outer side wall at a height of 3.3 m, which corresponds to the window height of a train. Other cable locations, e.g. under the ceiling, were not permitted. In Fig. 3.1 three different guide lines I, II, III are outlined. Line I was reserved for an older ALF-type cable only, whose results are not considered in this report. The synthesiser was always positioned on the platform side, the load near by the end wall.

3.2 Equipment

For the coupling loss a mobile measurement unit was used which consists basically of a computer controlled ESVD receiver from R&S and a tracking system which records the relationship between data and location by 40 samples per wavelength, see Fig. 3.2. The antenna orientations for the different polarisation planes are illustrated in Fig. 3.3. The software computes diagrams of coupling loss including the curve of reception probability with characteristic values of 5%, 50% and 95%. Furthermore it is possible to zoom sections of the whole measurement run in order to consider the different tunnel sections separately. For the measurements of reflection and cable losses standard equipment was used.

Figure 3.1:
Sketch of the Waterloo Tunnel in Hanover
COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Figure 3.2: Measurement Equipment for Coupling Loss

Figure 3.3: Antenna Orientations

\[2\text{-Dipole (30-to 900 MHz)}\]

\[
\begin{align*}
\lambda/2 &- \text{Dipole} \\
\text{perpendicular} & & \text{vertical} & & \text{horizontal}
\end{align*}
\]

\[\text{Logarithmic Antenna (above 900 MHz)}\]

\[
\begin{align*}
\text{horiz. perp.} & & \text{vertical} & & \text{horizontal parallel}
\end{align*}
\]
### 3.3 Measurement program

1. **Cable-types:**
   - **Coupled mode cables:** RLF 9/23, a cable with large slot spacing
     R-LFC 78, a quasi-slotted cable
   - **Radiating mode cables:** LK 37, RAY 78

2. **Frequency steps:** 30, 75, 145, 450, 900 MHz with λ/2-dipole 1800, 2000 MHz,
   coupled mode cables only with logarithmic-periodic antenna

3. **Cable losses and return losses**

4. **Coupling loss:**
   - **Antenna orientations:** horizontal parallel, vertical, perpendicular (dipole)
     horizontal perpendicular, horizontal parallel vertical (log.-per. antenna)
   - **Antenna heights:** 3.3 m, same as the cables, similar to free space measurements,
     also 2.0 m and 4.0 m
   - **Antenna distances:** 2.0 m standard, where possible 2.0 m from opposite wall

The results were investigated for the whole cable runs and for the two different tunnel sections separately.

5. **Field distributions:** at heights of 2.0 m, 3.3 m and 4.0 m

Cross section measurements of coupling loss were made in the greater tunnel section perpendicular to the cable in all antenna orientations.

### 4. RESULTS

Due to the great quantity of data it is impossible to report the results in detail in this paper. Thus only an overview is shown in Fig. 4.1 to 4.8 which seem to be relevant and representative diagrams.

#### 4.1 Cable loss and return loss

The results do not differ noticeably from the catalogue values.

#### 4.2 Coupling loss

Fig. 4.1 to 4.4 show the comparison of the coupling loss in free air and in the tunnel by the relevant values of reception probability of 5%, 50% and 95%. These considered measurements were made in the height of the cable in order to have comparable conditions to the standardised in free space. Only below 145 MHz greater differences became clear. Though the tendency of increasing coupling loss by decreasing frequencies is normal, measurement errors have not been clarified till now. Surprising is the fact, that the general behaviour of each investigated cable type in free air can also be
Comparison of performances of different leaky feeders in a metro tunnel

Reception probability at discrete frequencies
Antenna height: 3.3 m, antenna distance: 2.0 m

Figure 4.1: Coupling Loss of RLF 9/23 Cable
observed in the tunnel. Above 145 MHz the differences are typical in the range of ± 5 dB which seems to be related to the standing waves in the cross section, see paragraph 4.3. Figs. 4.5 to 4.7 show the coupling loss of the RLF 9/23 cable at 900 MHz where the two tunnel sections are considered separately. The differences are quite low and the mean values approximately 2 dB lower, only at parallel antenna orientations the behaviour is reversed.

These considered characteristics are typical in this type of tunnel. Results from other locations do not differ significantly. On the whole, the field characteristics can be explained as a superposition of free air characteristics and influences from the standing waves.

4.3 Cross section measurements

Fig. 4.8 shows the coupling loss in the cross section of the large part of the tunnel. It was measured at an antenna height of 3.3 m at 900 MHz at all antenna orientations. Evidently the RLF-type cable excites an electrical field of a standing wave. At greater distances than 2.0 m a field distribution with a regular periodicity of one wavelength can be observed of which the mean value is quite similar to that of measurements along the cable at equivalent antenna positions, compare Fig. 4.1. The deep and sharp minima should be noted. These field characteristics are typical for other antenna heights and frequencies as well. They demonstrate that small deviations in distance from the cable can lead to large changes in field strength.

5. CONCLUSIONS

This particular rectangular metro tunnel influences the field characteristics of the investigated cables installed on a side wall. The relevant values of reception probability are comparable with those measured in the free space. The maximum differences are in a typical range of ± 5 dB above 145 MHz. The influences on cables in the radiating mode are not greater than on cables in the coupled mode. The coupling loss measured in the tunnel section of smaller size is approximately 2 dB lower. A field of a standing wave in the cross section leads to a constant mean level which is similar to that measured at 2.0 m distance along the cable. The deviations are periodic with the wavelength.

6. ACKNOWLEDGEMENTS

The authors would like to extend their thanks to the UESTRA AG, Hanover, for their kind permission to use the tunnel and to Mr. Witwer for his good collaboration. Furthermore, they wish to thank Mr. Mahlandt from the Cable Development Department for his helpful advice and for his supply of software. Mr. H. Cyriacks is also thanked for preparing the large quantity of data.

7. REFERENCES

COMPARISON OF PERFORMANCES
OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Figure 4.2:
Coupling Loss of R-LCF 78 Cable
COMPARISON OF PERFORMANCES
OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Figure 4.3:
Coupling Loss of LK 37 Cable

Reception probability at discrete frequencies
Antenna height: 3.3 m
Antenna distance: 2.0 m, λ/2-dipole
COMPARISON OF PERFORMANCES
OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Figure 4.4:
Coupling Loss of RAY 78 Cable
COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

Figure 4.5:
Coupling Loss of RLF 9/23 Cable at the two Tunnel Sections from 20 to 80 m and 80 to 125 m

Antenna: 3.3 m height, 2.0 m distance, horizontal orientation
**COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL**

**Figure 4.6:**
Coupling Loss of RLF 9/23 Cable at the two Tunnel Sections from 20 to 80 m and 80 to 125 m

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Frequency (MHz)</th>
<th>Antenna Type</th>
<th>Antenna Gain [dBi]</th>
<th>Antenna Orientation</th>
<th>Antenna Height [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>r923</td>
<td>900,000</td>
<td>Half-wave Dipole</td>
<td>0.0</td>
<td>Vertical</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Antenna:** 3.3 m height, 2.0 m distance, vertical orientation
Figure 4.7:
Coupling Loss of RLF 9/23 Cable at the two Tunnel Sections from 20 to 80 m and 80 to 125 m

Antenna: 3.3 m height, 2.0 m distance, perpendicular orientation
Figure 4.8:
Cross Section
Measurements
at 900 MHz,
Antenna Height: 3.3 m
### COMPARISON OF PERFORMANCES OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL

<table>
<thead>
<tr>
<th>Distance between leakages</th>
<th>Geometrical characteristics</th>
<th>Electrical field</th>
<th>Electrical mode</th>
<th>Field characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d \rightarrow 0$</td>
<td>Continuously slotted</td>
<td>Noncoherent interferences</td>
<td>Coupled mode</td>
<td>Very irregular electrical field</td>
</tr>
<tr>
<td>$d \ll \lambda$</td>
<td>Quasislotted</td>
<td>Noncoherent interferences</td>
<td>Coupled mode</td>
<td>Very irregular electrical field</td>
</tr>
<tr>
<td>$d$ in order of $\lambda$</td>
<td>Special slot arrangements</td>
<td>Coherent interferences of spherical waves predominate</td>
<td>Radiating mode</td>
<td>Transverse electrical wave. Function of linear array</td>
</tr>
<tr>
<td>$d \gg \lambda$</td>
<td>Large distance between slots</td>
<td>Noncoherent interferences</td>
<td>Coupled mode</td>
<td>Very irregular electrical field</td>
</tr>
</tbody>
</table>

Table 3.1: Overview of modes
COMPARISON OF PERFORMANCES
OF DIFFERENT LEAKY FEEDERS IN A METRO TUNNEL