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TITLE **VDSL - Preliminary RFI measurements on Dutch burried cables**

STATUS For discussion.

ABSTRACT This TD describes an experiment on the radiation of buried cables. Due to the metalic shield (for mechanical protection) the observed radiation was significantly lower than the background noise in suburb areas. As a result, we see no reasons to exclude simple (low cost) VDSL modems from the VDSL standard, that have no notches in their signal spectrum.

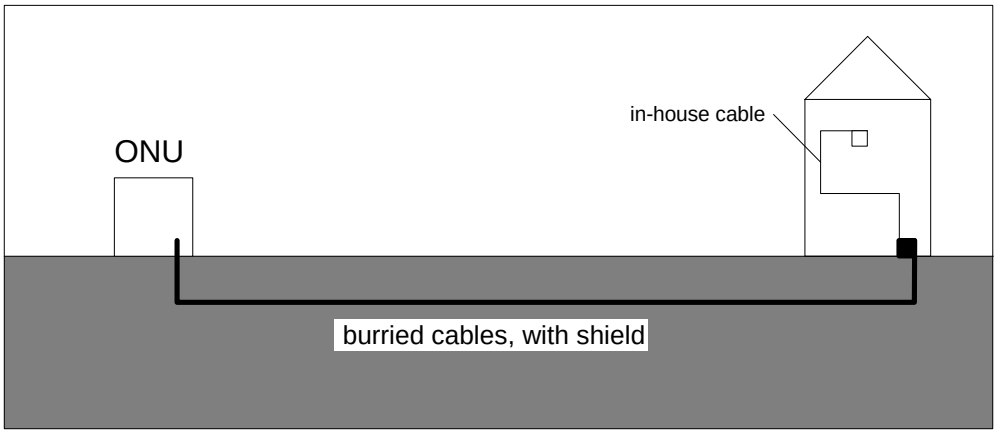

***Figure 1**. Situation, typical for the Netherlands. The VDSL signal, generated in the Optical Network Unit, is transported via burried cables. These cables are (mechanical) protected with a metalic shield, that reduces the RFI emission of the cable. Egress problems are expected only from in-house cables at the customer side of the network.*

1. Problem

VDSL downstream spectra are significantly wider than ADSL specta, and the emitted fields may interfere with radio fields. The situation that this egress prevents reception of radio stations, must be prevented. We identify three different situations, that deals with RFI egress:

1. The egress of network cables exceeds reasonable limits.
2. The egress of network cables can be ignored, except for the (unshielded) in-house cables.
3. All egress can be ignored.

These aspects may affect the VDSL requirements on spectral power density. Therefore, we identify three different solutions:

- In the first case, the level of the VDSL downstream spectrum should be reduced; at least at specific distress frequencies. It is possible that this is typical for areal cables, when they are unshielded, and sometimes even untwisted.
- In the second case, the RFI problem can be handled by improving the in-house networks. When the egress of cables in the optical network units (ONU's) causes problems, then it is relatively simple to shield them, or to shield the cabinet of the ONU. When the egress of cables at the customer side causes problems, then replacement of the in-house cables or reduction of the VDSL signal power are adequate solutions.
- In the third case, there is no need to solve any RFI egress problem.

KPN expects that solution 2 or 3 covers the majority of Dutch situations. This is because all cables between ONU and customers are burried, as illustrated in figure 1, and because the VDSL downstream signals are attenuated by the cable. We also expect that this holds for the majority of the European VDSL market, because burried cables are not uncommon, especially in urban areas where VDSL is planned.

When possible, reduction of overall VDSL power should be avoided, because it will reduce the overall performance. The same holds for a compromise solution with notches in the signal spectrum, because this may prevent low-cost solutions for VDSL. The experiment in this contribution indicates that it is unlikely that burried cables causes egress problems.

2. Description of the RFI experiment

To get some idea of the radiation of burried cables, we constructed the setup shown in figure 2. The total cable length of 1500m was winded on three big reels, just outside our laboratory The distance between the reels and the source and load was about 35m. A harmonic signal was injected at one side of the cable, that was terminated with 150Ω. No special precautions were taken to ground the metalic shield of the cable. The radiated field was detected, using a (loop) antenna and a receiver that was tuned on this frequency. The injected signal flows in hundreds of loops on the reels, and generates a cumulated field. This cumulated field simulates the effects of hundreds of VDSL signals flowing in different wire-pairs of a stretched burried cable.

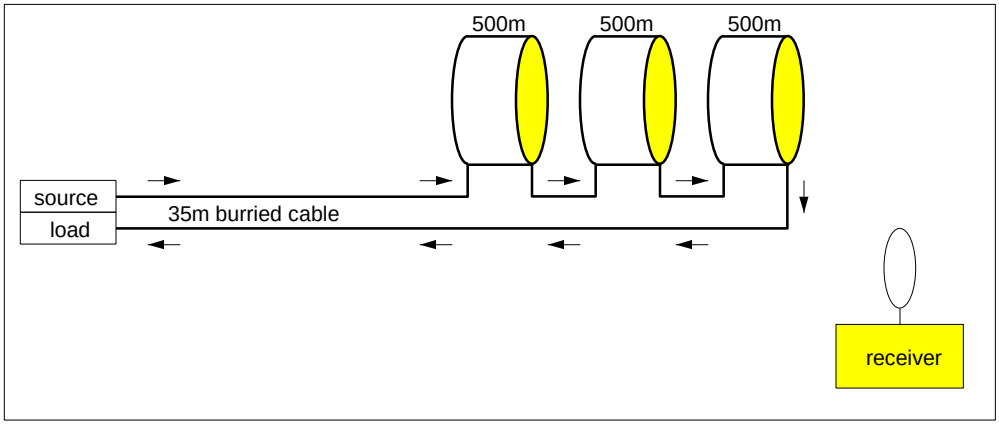

***Figure 2**. Experimental setup to measure the egress of 1500m twisted pair cable, winded on three weels. A harmonic signal was injected at one side of the cable, that was terminated with 150W. The radiated field was detected with a (loop) antenna and a receiver that was tuned on this frequency.*

Table 1 shows the measured magnetic fields, and table 2 the instrument that were used. The radiated fields were measured when +20dBm source power was injected in the cables, and with a loop antenne at a distance of <5m of the reels. Below 10MHz, we were able to detect the radiated (weak) field, but at 10MHz the background noise was significantly higher than the radiated field (at +20dBm source power).

freq (1) [MHz]	radiated field [dBµA]	background noise (A) [dBµA]	background noise (B) [dBµA]	background noise (C) [dBµA]	background noise (D) [dBµA]	background noise (E) [dBµA]	background noise (F) [dBµA]	noise floor [dBµA]
0.95	–32	–32.0	-37	-38 .. -35	-35	-34 .. -29	-32 .. -28	–44.8
2	–32	–39.4	-36	-39	-38 .. -35	-40 .. -31	-39	–44.8
3	–34		-40 .. -33	-37	-34 .. -31	-38 .. -31	-36	
5	–21		-37 .. -31	-34 .. -29	-34 .. -25	-35 .. -26	-34 .. -29	–45.1
6.7	–31		-37 .. -31	-34	-33 .. -31	-38 .. -31	-36 .. -32	–45.1
10	???		-25 .. -21	-12 .. -7	-13 .. -10	-28 .. -15	-14 .. -11	–45.1

***Table 1**. Measured magnetic H-fields, using the equipment summarized in table 2, at 2.4kHz resolution bandwidth. The second column is the detected harmonic field, when +20dBm harmonic source power is injected in the cables. The columns with background noise represent the detected random fields, when the sourcepower was switched off. It was measured in the open air, close to the lab (with many computers) as well as at various suburb area's. The noise floor of the antenna+receiver was measured in a shielded anechoic chamber.*

Instrument	manufacturer	model
Signal source	Adret	7100D
Matching baluns	North Hills	0400BB
Active loop antenna	R&S	HFH-Z
Measurement receiver	R&S	ESH3

***Table 2**. Instruments used in the setup of figure 2*

3. Analysis of the RFI experiment

Our radiation experiment with a harmonic source is indicative for the egress that is to be expected from buried cables when VDSL signal are transported. Figure 3 shows an example of a VDSL spectrum, that meets the requirements as they are adopted for the time being. When this signal is detected with a radio receiver having 2.4kHz as resolution bandwidth, then it will detect –26dBm signal power. The same applies for a -26dBm harmonic source.

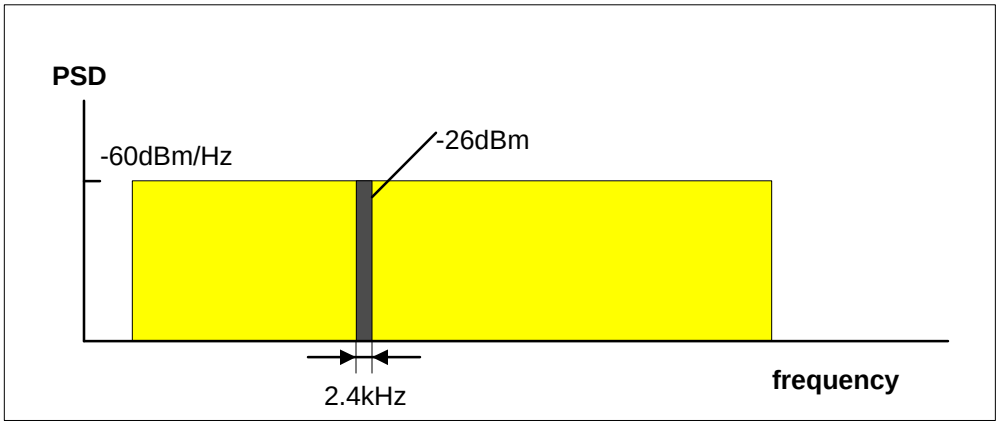

***Figure 3**. Example of a the VDSL spectrum*

In our experiment, we used a harmonic source, at a level that is 46dB higher than an equivalent VDSL band. This means that the radiated fields, summarized in table 1, are 46dB lower when a VDSL signal was used. **These levels are *significantly* lower than background noise levels in suburb areas**. Our experiment was based on a loop antenna, which detects magnetic fields. In practice, radio amateurs use long-wire antenna's as well, to detect electrical fields. This is illustrated in figure 4.

The sensitivity between these antenna's may differ, but the ratio between a radio signal level and background noise level are similar when receiving (far) fields. As a result, the use of long-wire antenna's would have result in similar observations.

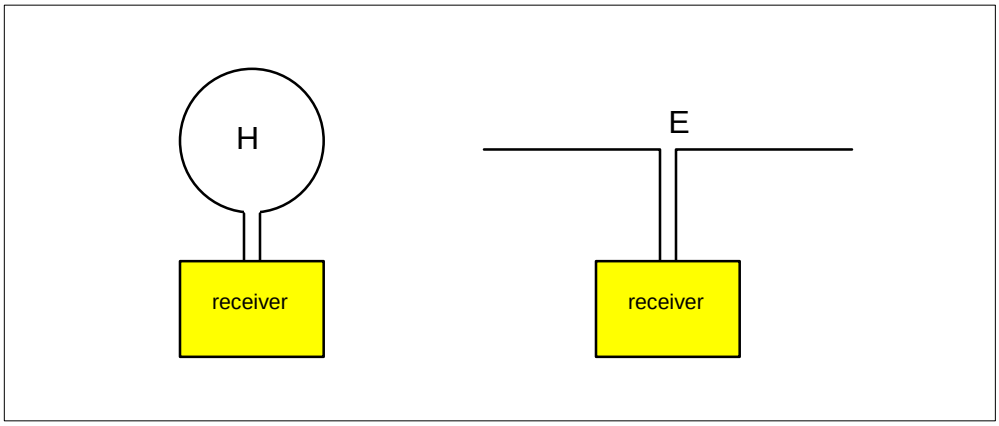

***Figure 3**. The sensitivity of loop antenna's and long-wire antenna's may differ, but the ratio between a radio signal level and background noise level are similar when receiving (far) fields.*

4. Conclusions

We described an experiment on the radiation of burried cables. The detected radiation, measured from a +20dBm harmonic source, was weak with respect to the background noise of suburb areas. VDSL signals are 46dB lower (when detected with 2.4kHz resolution bandwidth), so we found no reasons to expect that the egress of burried cables by VDSL will cause any serious problem. If egress problems occur in the Netherlands, we expect them only with *in-house cabling at the customer side*. This will be an aspect of further investigation.
As a result, KPN proposes:

If egress requires in some cases the need for notches in the VDSL spectrum, then we propose to define at least *two* options:

- A simple variant for VDSL without notches
- A complex variant for VDSL with user-definable notches

Both variants may support back-off to reduce the overall (spare) VDSL power at short links.