TRANSMISSION POSSIBILITIES IN RAILWAY DATA NETWORK TODAY

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Abstract *– The major switch to new transmission technologies in large systems is much slower than the progress of research. Therefore track side copper cables in railway environment will not be easily replaced in the next 10 years due to technology of communication, rigid standards and recommendations related to traffic. In this paper we will analyze some issues of Serbian railway data network based on copper cables, comparing it to international trends. Since the overall reconstruction of communication lines along the track have not started yet, copper links for voice as well as data still depend on the use of installed cables. The xDSL technologies, mainly TC-PAM are the preferable type used for data transmission along the railway lines. Bonding (using n pairs instead of one) and improvements in rate (variations of TC-PAM) foresee yet a decade at least for use of this technology. Standards related to mentioned transmission systems and media dealt with standard diameter wires, that most telecom operators use. Since railway owns cables with pairs/quads with a better low frequency characteristics and a greater diameter this paper deals with estimations of possible range and linerate of existing transmission system in railway environment. Regarding existing standards, their theoretical consideration and achieved rates on certain cable spans this paper analyze the possibilities of copper cables, quantitatively. The aim is to help in the process of increasing effectiveness of systems as well as to point out the weak links of the systems.*

Keywords – railway trackside copper cables, xDSL, transmission.

1. INTRODUCTION

Although optics brought so much bandwidth and opportunities to operators, they still tend to use the copper that is already in the ground and have satisfactory characteristics. Since the overall change of railway transmission systems have not started, the trackside (line side) copper cables intended for baseband communications is still an option. The single-pair high speed digital subscriber line (draft name of the standard was G.SHDSL) was described in ITU-T 991.2. The main difference of this transmission system from the rest of the members of xDSL family is a Trellis Coded PAM modulation used. The TC PAM uses frequencies in the baseband transmission ragne. The data rates are symmetrical in upstream and downstream [1,2].

When the odds were severely against the SHDSL and pro fiber, additions came to light, bringing possibilities for expansion of data rate. Using several pairs at the same time the data rates could be significantly increased. Applying new TC PAM modulations involving 32 and 64 states (now even 128) combined with multi pair bonding could enable the streams comparable to fiber transmission (depending on the actual span distances, TCPAM used and number of pairs). Since the fiber evolution of Serbian Railway Infrastructure is still on hold this could provide the survival with moderate increase of capacities for existing network and it will make a small but efficient backup for certain small linerate consuming applications in the near future. The copper cables still have their purpose in communication of traffic oriented staff and maintenance staff, it survival and future is certain as long as the regulations in this area are not changed (Rule books in various areas of railway, recommendations, etc.) [1-5].

Dealing with the negative influence of traction

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system (25kV, 50Hz) is another task characteristic for railway environment. Close proximity of copper cables used for transmission to overhead contact line also presents danger for employees involved in maintenance [6].

The rest of the xDSL family has its use in the railway environment but the SHDSL transmission is the dominant type used. The VDSL and VDSL2 are applied in larger stations and are supported by local copper cable networks as transmission media. These types of modems have their use in forming an environments resembling campus structure. The ADSL is used only as a connection to public network and is slowly approaching retirement. Among mentioned members of the xDSL family solutions as well as modulations vary but TC PAM is among other benefits, the modulation able to withstand harsh railway conditions and still reach a significant distance.

2. SHDSL LINES IN RAILWAY ENVIRONMENT

Modems using modulation TCPAM 16 are in use on the entire data network of Serbian Railway Infrastructure. Devices are connected to symmetrical pairs contained in the last layer of railway trackside copper cable. This layer also incorporate symmetrical pairs (quad) for TDM transmission systems (12 channels) and coaxial pair for 300 channels transmission system on some lines. All this lead to the conclusion that some interference, crosstalk and noise is inevitable.

2.1. Modems

Modems used in network of Serbian Railway Infrastructure are mostly type Watson 5 (Schmid Telecom) TC PAM 16 based. In stations along the railway lines these modems are installed in train dispatcher rooms which are occupied 24/7. No special environmental conditions were applied so a table top variant is chosen in order to achieve better cooling conditions in racks. Modems have adapters for power supply AC/DC 240V, 48DC, 15W. The ground of this version of modem is normally floating when referenced to earth (tip and ring of the telephone connection) [7].

There is a possibility to use remote Monitoring through Telnet on the Watson 5. After connection is established, the main menu offers several possibilities: performance management, fault and maintenance management, configuration management and security and remote management. Modems used could achieve up to 2048kbps (nx64kbps) rate. Line rate is calculated using following equation

$$Linerate = n \times 64\ kb/s \quad (1)$$

where n is a number of time slots per pair (for TC PAM 16; n=3,4,..). When multiple are used this equation becomes

$$Linerate = m \times n \times 64\ kb/s \quad (2)$$

where m is a number of pairs used in the span. Previous leads to the overall physical DSL synchronization rate

$$Syncrate = n \times \frac{64kb}{s} + OH\ [\frac{kbits}{s}] \quad (3)$$

and OH represents *SHDSL Overhead* (8kbit/s including 3.2kbit/s of the EOC – Embedded Operations Channel, channel for management purposes). Sync rate determines the SHDSL reach.

Signal quality (SQ) is several times addressed in this paper representing the calculated noise margin (merit of transmission quality) and defined as follows

$$SQ = SNR1 - SNR0, \quad (4)$$

where SNR1 is a signal to noise ratio calculated by the transceiver by analyzing the error correction bits (trellis bits) in the line code and SNR0 is the signal to noise ratio that gives a bit error rate of 10^{-7} in presence of average Gaussian noise. For TC PAM 16 the theoretical value for SNR0 is 27.7 dB [7].

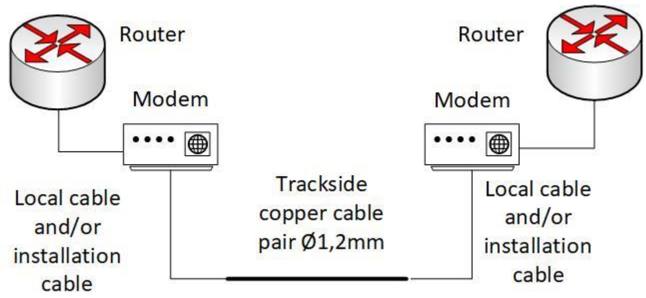
2.2. Copper pairs

Copper cables are so called STKA and STA cables, custom made for railway use, consisting mostly of pairs (quads) for the use in baseband (voice band for various dispatching and party lines along the railway tracks). First layer consists of quads with wires of 0.9mm diameter. Second layer is similar to first having more of the same quads. Third layer is larger and incorporates symmetrical quads (pairs) of 1.2mm diameter and coaxial pair 1.2/4.4mm (300 channels transmission systems, STKA cable) or high frequency quad (12 channel transmission systems, 120kHz, STA cable). Cable is with air/paper isolation, Al sheath, armature made of two Fe strips and external protection based on PVC. Depending on needs (different for every line) certain number of quads/pairs is loaded in order to achieve better transmission characteristics in voice band.

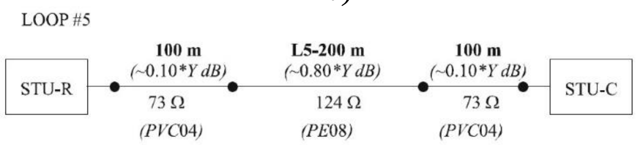
Pair used for SHDSL transmission is symmetrical of 1.2mm diameter with no load (sometimes if needed for smaller distances up to 5km is used pair with wires of 0.9mm diameter – mostly in urban areas). These pairs are terminated in buildings for signaling and telecommunication equipment in stations. From here pairs in local subscriber cables are used. This scenario is similar to one represented in ITU-T 991.2 (Annex B, tet loop #5) Fig.1 [3].

To its similarity is adding the fact that cables shown in the recommendation are of the wire diameter

0.8mm which is the largest diameter addressed in this recommendation.



a)



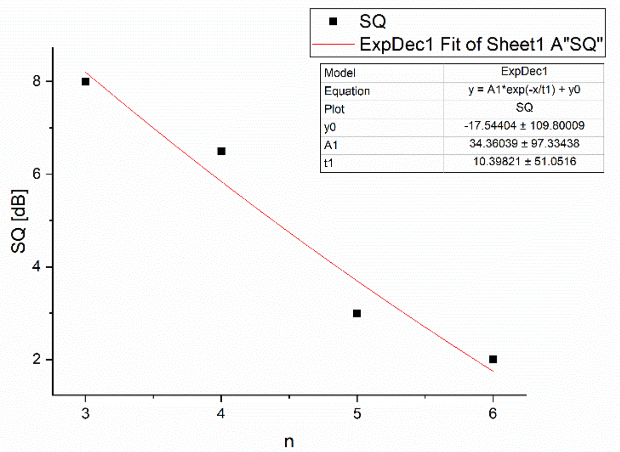
b)

Fig.1. Typical configuration in stations (a) corresponding to ITU-T G.991.2 Annex B test loop #5 (b)

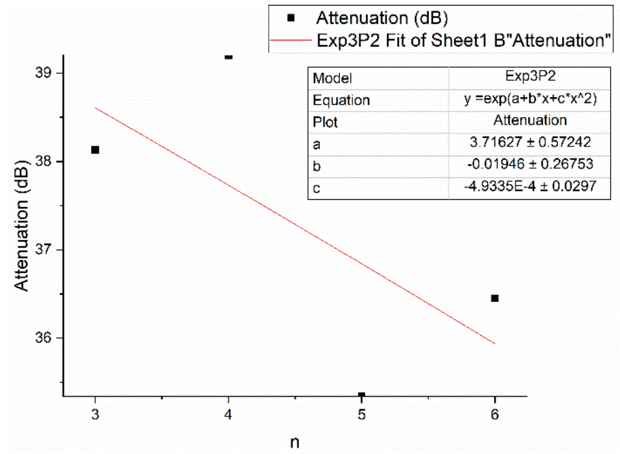
3. RESULTS AND DISSCUSION

Since different lengths of cables (spans) could be found across the network, different linerates and conditions of cables, a comparison of these differences could provide valuable information about the possibilities of network. By changing the linerates of modems (nx64kb/s) i.e. number of timeslots used the results of different conditions are presented in Fig. 2. for span Kosjerić – Valjevo. Deterioration of SQ and attenuation are mostly following exponential or polynomial (linear or square - in smaller number of cases) curves so these dependancies are used for fitting of data.

Comparison of different spans and achievable linerates on these spans is presented in Fig.3.



a)



b)

Fig.2. Characteristic of transmission on span Kosjerić – Valjevo (~39km) for different n (number of 64kb/s quants) of a) signal quality (SQ) and b) attenuation

When Fig. 3. is compared to the one obtained using recommendation data, Fig. 4. the similarities can be quantitatively evaluated. It is yet a task to collect enough data for these cables in the light of SHDSL transmission, since this was not their primarily intended use.

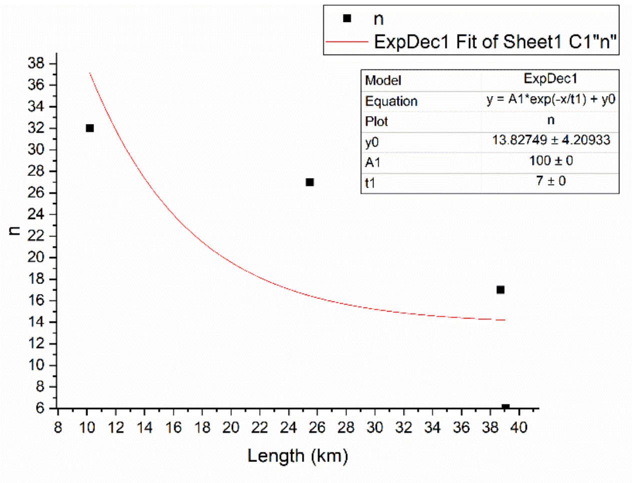


Fig.3. Achieved number of timeslots (linerates) vs different cable lengths

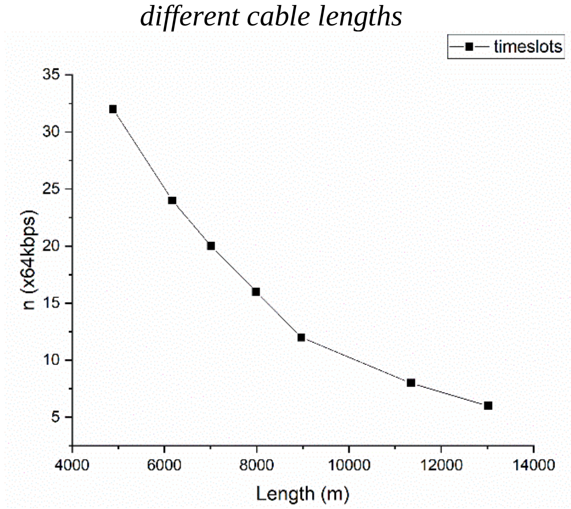


Fig. 4. Linerate vs distance curve obtained using data from the ITU-T G.991.2 noise model B,C,D [3]

Fig 3. and 4. compared indicate trackside copper cables have significantly better transmission characteristic concerning SHDSL modems.

It is also a task to determine the advantage achieved with air/paper isolation since recommendation is strictly oriented towards subscriber cables using PE or PVC as insulator.

Regulations dealing with copper cables (baseband, mostly voice band used) clearly show that cables with air/paper isolation compared to those with plastic mases isolation have lower attenuation coefficient and relative attenuation (relative to 800Hz – since their primary use in the voice band) [2]. Railway trackside cables also have significantly wider wires diameters (0.9 and 1.2mm) compared to subscriber cable wires diameters (0.4; 0.6 and 0.8mm) so a better characteristics than those given in recommendation were expected.

4. CONCLUSION

Customary copper cables used on railway having air/paper isolation shown very good characteristics in SHDSL network installed during previous decade. Comparing to subscriber cables using mostly plastic masses better transmission characteristics were shown. One of the best aspects of STKA/STA cable was reduction factor minimizing the influence of traction system.

It seems that SHDLS technology improved with mentioned possibilities, has a future in railway environment. Existing lines could increase its possibilities providing users better connections to railway centers in the means of higher linerates or increasing signal quality. It could also be improved by adding equipment in smaller stations between already equipped stations, although this is not justified at times. Certain stations are not staffed and the trends show that this will continue thus having a larger area of control from larger stations. Since the SHDSL network is mostly oriented towards train dispatchers and administrative use it is reasonable to expect that the trend of decrease of staffed stations, will replicate itself to network here explained.

If stalling of fiber optics era continues, railway multiplication of bonds between stations is expected, but only as a means of network survival. SHDSL network will certainly still be applicable in the fiber era since old copper cables have reached even the smallest objects along the lines with its numerous branches (APB block buildings, Ground train radio RDV buildings, Level crossing buildings, remote block building in stations, junctions…) and it is not expected to make a similar number of branches covering all the places previously covered (with copper cables), on future broadband oriented fiber optic cables. Railway trackside power cable (PNK) is present in most of the previously mentioned locations so powering doesn't have to be remote through communication copper cable, which would be a noise and interference source influencing other communication systems using trackside copper cable.

Entering every point of interest along the tracks with fiber optic cable would be extremely costly and it would deteriorate the characteristics of the cable. However, the fiber will cover most of the spots along the line, thus shortening the spans of future SHDSL links, what will have a significant impact on the achievable linerates and signal quality for future uses.

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