Organization of video surveillance at railway crossings

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Abstract. Currently, the railway industry requires railway telecommunication networks to provide modern, high-quality services to manage the transportation process. All types of railway transport are in dire need of proven and standardized wireless technologies for various purposes: mobile communications, wireless access, short-range communication. The use of wireless technologies should become one of the main directions of innovative development of railway transport, increasing its efficiency and safety and, as a result, competitiveness and attractiveness for passengers and shippers.
Key words: train radio communication, video surveillance, mobile communication, train safety, timeliness of train arrival, level crossing, wireless communication, Wi-Fi.

1. Introduction

A dangerous element of the transport network, as well as a significant impact on the efficiency of operation of road and rail transport, is the intersection of railways and highways as a whole. And this problem of level crossings is relevant for all developed countries [1-3].
These intersections are characterized by road traffic accidents, i.e. at level crossings, including those with particularly serious consequences. As statistics show, all cases of accidents occur due to violation of safety rules in the area of operation of railway transport [4,5].
The rapid pace of development of motorization is the main factor that creates additional prerequisites for the deterioration of the situation in the field of traffic safety through level crossings [6].
Currently, the issues of ensuring traffic safety through level crossings and reducing the number of accidents on them are acquiring special significance. Depending on the traffic intensity at the crossing, the following types of guarding devices are used; automatic traffic light signaling; automatic traffic light signaling with automatic barriers; automatic warning alarm with non-automatic barriers.

2. Materials and Methods

To select the type of enclosing devices, it is necessary to be guided by their category (table 1) [7].

Table 1. Categories of Fencing Devices

1-category	2-category	3-category
the intersection of the railway with highways of 1-2 categories, streets and roads with tram and trolleybus traffic with traffic intensity on the crossing of more than 8 train-buses in 1 hour	intersections with highways of 3 categories, streets and roads with bus traffic on the crossing of less than 8 train-buses in 1 hour, with other roads, if the traffic intensity on the crossing exceeds 50 thousand train-crews per day or the road crosses three main railway lines ;	intersections with roads that do not meet the characteristics of category 1 and 2 crossings, as well as if the traffic intensity on the crossing with satisfactory visibility exceeds 10 thousand. train-carriages, and in case of unsatisfactory (bad) visibility -1 thousand train-carriages per day.

Visibility is considered satisfactory if, at a distance of 50 m or less from the railway track, a train approaching from either side is visible at least 400 m, and the crossing is visible to the train driver at a distance of at least 1000 m.

In order to timely close the crossing when a train approaches it, the length of the approach section is calculated.

Time required to notify a train approaching a crossing:

$$t_c = t_1 + t_2 + t_3, \quad (1)$$

Where is t_1 the time required for the car to follow the crossing, s;
t_2 – response time of devices for signaling and signaling control circuits;
t_3– warranty time.

Time t_1 is determined by the formula:

$$t_1 = \frac{l_П + l_Р + l_0}{V_Р}, \quad (2)$$

Where is $t_п$ – the length of the crossing, determined by the distance from the crossing traffic light (or half-barrier) farthest from the extreme rail, to the opposite extreme rail plus 2.5 m;
l_p – estimated vehicle length
l_o – distance from the place where the car stops to the crossing traffic light or SPD;
v_p – the estimated speed of movement of the car through the crossing.
Estimated length of the approach section:

$$L_P = 0{,}28 v_{max}\, t_c = \ 0{,}28 v_{max} \left(\frac{l_p + l_p + l_p}{v_p} + t_2 + t_3 \right), \quad (3)$$

where 0,28 – speed conversion factor from km / h to m / s;
v_{max} – maximum speed of train movement, set on this section, km / h.

At present, new construction materials are being introduced at the operated crossings, promising technical solutions are being developed and implemented, aimed at ensuring the safe and uninterrupted movement of vehicles and rolling stock of railways. In particular, railroad crossing barriers (UZP) are being introduced, designed to prevent unauthorized vehicles from leaving the crossing. Modern systems of automatic crossing signaling (APS) and automatic barriers (ASH) have a number of disadvantages that do not allow to ensure a high level of traffic safety at level crossings [1-5].
Firstly, they lack objective control over the situation at the level crossing and timely warning of the driver about an emergency at the level crossing. This can be eliminated by installing video cameras at the crossings and organizing a direct channel with the train driver approaching this crossing (Fig. 1) [8-14].

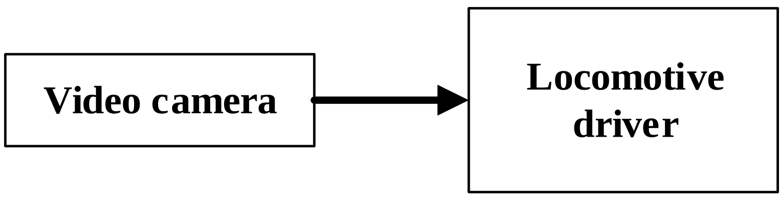

Figure 1. Organization of a direct channel between the locomotive driver and the crossing

To make the right decision, the driver must be able to assess in advance the situation at the crossing by video (at a distance of at least 2 km before the crossing) and brake in time without damage [7]. The simplest option is to install video cameras at the crossing, and the transmission of video images to the driver's cab can be carried out using wireless technologies, as well as the organization of communication with the driver is carried out through classical train radio communication (PRS) [15-19]. Therefore, it is necessary to solve two problems:

1 task - the choice of the optimal video camera;

2 task - the choice of wireless access technology to ensure the transmission of video images.

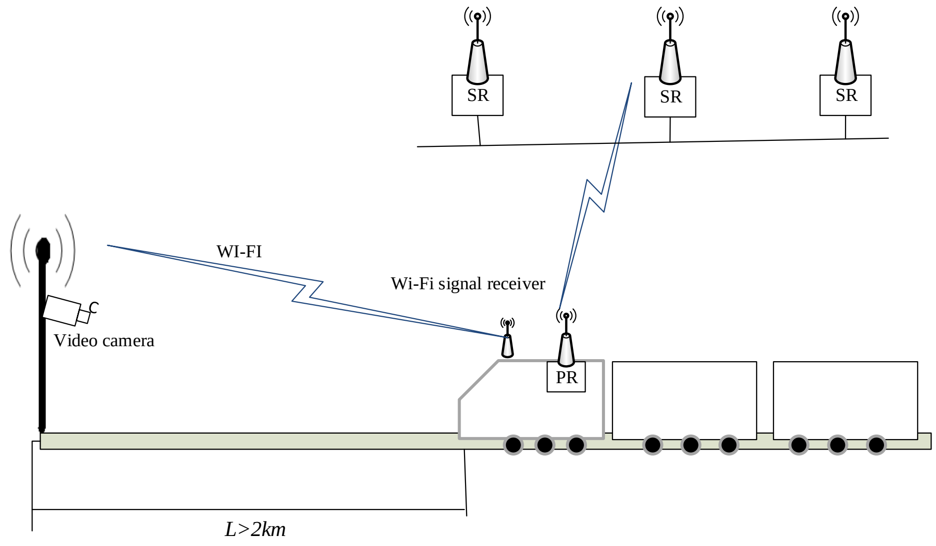

Figure 2. Organization of train radio communication and a direct channel between the locomotive driver and the crossing

3. Results

1 task.

Strict requirements are imposed on video cameras, since they are installed outdoors and must be reliable, and it is also necessary to take into account the operating conditions, or rather the operating temperature. At the stage of selecting cameras, it is necessary to accurately determine all goals and objectives and, based on these inputs, purchase equipment. For example, you can use an AHD-H outdoor video camera with a varifocal lens, version UHL-1 [20] (Fig. 3). Table 2 shows the main characteristics of an outdoor AHD-H video camera with a varifocal lens, version UHL-1 (GOST 15150-69).

Figure 3. Outdoor video camera AHD-H with a varifocallens, version UHL ITECH PRO AHD-OV 2 MP THERMO

Table 2. Main characteristics of AHD-H outdoor video camera with varifocal lens UHL-1 version (GOST 15150-69)

Matrix	1/2.8" SONY CMOS IMX322 + NVP2441H
Matrix resolution	1920x1080 (2 Mp)
Video standard	AHD-H (AHD 2.0)
Minimum illumination	0,001 lk
Lens	f=2,8-12 mm
IR illumination range	< 40 m
Signal to noise ratio	> 52 dB
Add. function	D-WDR; AGC, BLC, ATW; 2D/3D-NR; Defog; Sens-up 2-30x; day/night. OSD menu for picture adjustment
Working temperature	-60°C +50°C

DC power	12B
Current consumption	1,1 A
Dimensions (edit)	295x84x120mm
The weight	1,7 kg

A varifocal lens is a type of lens with a variable focal length. This lens allows you to adjust the distance to the object of observation, thereby making it possible to examine in more detail one or another detail of what is happening. At the same time, it does not spoil the image quality and does not reduce the detail when scaling.
This type of cameras can also be used in large-area objects. When installing a camera with a varifocal lens, you need to adjust the focus, after which it will be fixed in the position you have chosen and after that manual adjustment is required only if you need to change the camera's angle of view.
2 task.
Currently, great attention is paid to energy efficient data transmission technologies and the use of IoT (*internet of things):* FSO *(free-space optics)* [AOCL - *atmospheric optical communication lines*], LPWAN (*Low Power Wide Area Network*) [long-range energy efficient network]. As well as technologies that can provide services to passengers at stations (train stations) and directly when the train moves inside it: WiMAX (*Worldwide Interoperability for Microwave Access)*, Wi-Fi (*Wireless Fidelity*).
Any system (technology) can simultaneously meet only two of the three technical characteristics: transmission speed, energy efficiency and communication range (Fig. 4).

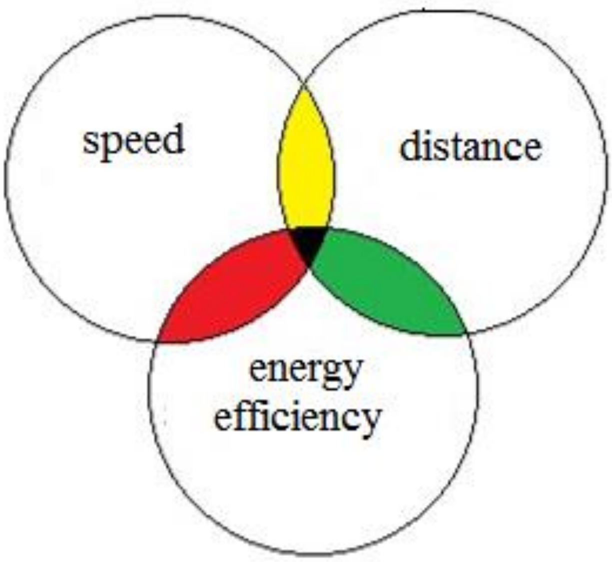

Figure 4. Relationship of technical characteristics of wireless communication systems

At the present stage of development of network technologies, the technology of wireless networks Wi-Fi is the most convenient in conditions requiring mobility, ease of installation and use. The main Wi-Fi bands are 2.4 GHz / 12 cm (2412 MHz-2472 MHz) and 5 GHz / 5 cm (5160-5825 MHz). A promising direction in the development of Wi-Fi technology is the use of frequency bands above 5 GHz. This makes it possible to transfer large amounts of payload data in real time. The channel spacing in the 5 GHz range is 5 - 20 MHz, and the channel width is 20 MHz. Thus, the spectrum of the operating frequencies of the equipment also overlaps with independent channels, the operation of which is possible without mutual interference – 22 [21-27].
On each channel, you can connect up to 4 wireless cameras, in total, it is possible to connect 88 cameras using wireless communication in the 5 GHz range.
A Wi-Fi signal can be transmitted for kilometers even at low transmit power, but a high gain antenna is needed to receive a Wi-Fi signal from a conventional Wi-Fi router over a long distance. Wi-Fi wireless technology is based on IEEE 802.11 standards. The IEEE 802.11n standard is based on OFDM-MIMO technology. Many of the technical details implemented in it are borrowed from the 802.11a standard, but the IEEE 802.11n standard provides for the use of both the frequency range adopted for the IEEE 802.11a standard and the frequency range adopted for the IEEE 802.11b / g standards [28-38].

MIMO technology (Multiple Input Multiple Output; multiple inputs, multiple outputs) will increase the channel speed of the wireless connection from 54 Mbps to over 300 Mbps.
MIMO is a method of spatial signal coding that allows to increase the channel bandwidth, in which two or more antennas are used for data transmission and the same number of antennas for reception. Transmitting and receiving antennas are spaced apart so as to achieve minimal mutual interference between adjacent antennas.
MIMO technology uses multiple antennas of different kinds tuned to the same channel. Each antenna transmits a signal with different spatial characteristics. Thus, MIMO technology uses the radio spectrum more efficiently and without compromising operational reliability.
Another plus of MIMO technology is that it provides Spatial Division Multiplexing (SDM). SDM spatially multiplexes multiple independent data streams simultaneously (mostly virtual channels) within a single spectral channel bandwidth.
The only drawback of using MIMO is the complexity and bulkiness of the system and, as a result, higher power consumption.
Let's make a calculation to determine the range of the Wi-Fi technology channel.
To calculate the range of the channel, we determine the total gain of the transmission system by the formula:

$$Y_{dB} = P_{t,dBm} + G_{t,dBi} + G_{r,dBi} - P_{min,dBm} - L_{t,dB} - L_{t,dB}\ , \quad (4)$$

Where is, $P_{t,dBm}$ – transmitter power (nameplate data of the device);
$G_{t,dBi}$ – transmitting antenna gain (passport data of the device);
$G_{r,dBi}$ – the gain of the receiving antenna (passport data of the device);
$P_{min,dBm}$ the sensitivity of the receiver at a given speed;
$L_{t,dB}$ – signal loss in coaxial cable and connectors of the transmitting path;
$L_{t,dB}$– signal loss in coaxial cable and connectors of the receiving path.

Next, we define the loss in free space by the formula:

$$FSL = Y_{dB} - SOM, \quad (5)$$

Where is SOM (System Operating Margin) – radio energy margin (dB), which takes into account possible factors that negatively affect the communication range, such as:
− temperature drift of transmitter sensitivity;
- all kinds of atmospheric phenomena: fog, snow, rain;
- mismatch of antenna, receiver, transmitter with antenna-feeder path.
The SOM parameter is usually taken equal to 10 dB. It is believed that such a gain margin is sufficient for engineering desig [39].
To calculate the communication range between two points for a different range (F), you must use the formula:

$$D = 10^{\frac{FSL-33}{20} - lgF}. \quad (6)$$

802.11 equipment operates at 2.4 GHz and 5 GHz. Different frequencies have their own advantages and disadvantages. At a frequency of 2.4 GHz, you can achieve an increase in the range of the signal, but the power will decrease and the number of devices connected to the router will decrease. Conversely, at 5 GHz, you can increase the power, but the range of the signal will be much shorter.
The 2.4 GHz frequency is by far the most common for transmitting information over Wi-Fi. This frequency has quite a few non-overlapping channels - 3, while the 5 GHz frequency uses 19. Such a small number of channels can cause loss of speed and even quality of data transmission, which will be noticeable when exchanging packets in real time.
One of the negative factors is the presence of "spurious noise" in the wireless channel, which degrades the signal flow.
Devices with 5 GHz support can work directly without latency, because have more non-overlapping "bands", and even deliver higher speed than at 2.4 GHz [40].

For example, let's choose a Satnadart 802.11 a/n/AirMax router operating at a frequency of 5 GHz (Table 3).

Table 3. Main characteristics of a Wi-Fi standard router

Wi-Fi standard	802.11 a/n/AirMax
Bandwidth	450 Мбит/с
Working range	5GHz
Multi-stream data transmission	MIMO
Transmitter power	26 dBm
Antenna gain	16 dBi
Receiver sensitivity	-92 dBm

Let's calculate the communication range for this type of router at an operating frequency of 5 GHz:

$$Y_{dB} = 26 + 16 - (-92) = 114\, dB,$$

$$FSL = 134 - 10 = 124\, dB,$$

$$D = 10^{\frac{130-33}{20} - lg5000 =} 7{,}24\, km.$$

4. Conclusions

Thus, with the right approach to choosing video cameras, you can organize the safety of train traffic at crossings and minimize accidents on the stretch. The model operates at a frequency of 5 GHz, which, although it imposes some requirements regarding the presence of a line of sight, but also makes it possible to transmit at higher speeds.

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