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Method for detecting the source of radio interference affecting train radio communication in the band of 2.13 and 2.15 MHz

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ABSTRACT There are many factors that influence the process of organising train movements, quality radio communication being one of the most important.

The intelligibility of the dispatcher's commands to the driver is important in deciding what action to take, and in informing the dispatcher of the train situation on a particular section of the track.

Sources of radio interference that have an interfering effect on the quality of the train radio signal are natural and artificial interference. The sources are mainly low-frequency interference. One of the constant sources of high-frequency emissions that affect stable operation of train radio communications refers to discharges generated in the high-voltage insulation of power lines, including discharges generated in the insulation of overhead wires.

Spark discharges, the source of radio interference, occur both on the surface of the insulator (usually called surface partial discharges (SPD)) and inside the insulation (such discharges are called partial discharges (PD)). In the operation of high voltage insulation, those insulators that contain PD and PPD are called defective insulators. PD and PD diagnostics are carried out twice a year by means of a laboratory car. Discharge registration is performed in the visible and ultraviolet range. There are acoustic methods for registering PD and SPD. It is proposed to register discharges in the electromagnetic frequency range.

For prompt detection radio interference, it is recommended to place antennas on the laboratory car, and combine measurements with current diagnostics of high-voltage insulation, that will allow increasing reliability of the results received in the course of diagnostics. To increase the accuracy of radio interference source detection, two antennas are considered to be placed on the laboratory car.

KEYWORDS: radio interference; high voltage diagnostics of overhead line insulation; train radio communication; partial discharges; and surface partial discharges

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Научная статья

Способ обнаружения источника радиопомех, влияющих на работу поездной радиосвязи в диапазоне 2,13 и 2,15 МГц

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АННОТАЦИЯ На процесс организации движения поездов влияет множество факторов, качественная радиосвязь является одним из важнейших.

Разборчивость команд диспетчера, направленных машинисту, важна для принятия решения о каких-либо его действиях, а также при информировании диспетчера о поездной ситуации на конкретном участке железной дороги.

Источниками радиопомех, оказывающих мешающее воздействие на качество полезного сигнала поездной радиосвязи, служат естественные и искусственные помехи. В основном источники вырабатывают низкочастотные помехи. Одним из постоянно действующих источников высокочастотного излучения, оказывающих влияние на устойчивую работу поездной радиосвязи, являются разряды, возникающие в высоковольтной изоляции линий электропередачи, в том числе разряды, образующиеся в изоляции контактной сети.

Искровые разряды — источник радиопомех — образуются как на поверхности изолятора (как правило, их называют поверхностными частичными разрядами (ПЧР), так и внутренней толще изоляции (такие разряды называются частичными разрядами (ЧР)). При эксплуатации высоковольтной изоляции те изоляторы, которые содержат ЧР и ПЧР, называют дефектными. Диагностику ЧР и ПЧР проводят два раза в год посредством вагон-лаборатории. Регистрацию разрядов выполняют в видимом и ультрафиолетовом диапазоне. Существуют акустические методы регистрации ЧР и ПЧР. Предлагается регистрировать разряды в электромагнитном частотном диапазоне.

Для оперативности выявления радиопомех антенны рекомендуется разместить на вагоне-лаборатории, а измерения совместить с действующей диагностикой высоковольтной изоляции, что позволит повысить достоверность полученных во время диагностики результатов. Для увеличения точности определения источника радиопомехи на вагоне-лаборатории рассматривается размещение двух антенн.

КЛЮЧЕВЫЕ СЛОВА: радиопомехи; высоковольтная диагностика изоляции контактной сети; поездная радиосвязь; частичные разряды; поверхностные частичные разряды

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INTRODUCTION

The intelligibility of speech in train radio operation is essential, so it is important to ensure that this critical form of dispatch communication remains up and running at all times. However, there are a number of factors that interfere with the smooth operation of the train radio communication. Such analysis is given, for example, in work [1].

One of the main causes of radio interference source are partial discharges (PD) and surface partial discharges (SPD) [2–4]. Attempts have already been made to localise the source of interference. Such a possibility has been considered in [5]. Earlier studies [6–10] have determined that diagnostics should be performed in the frequency range of 1 to 80 MHz. It is expedient to make the antenna with the necessary radiation pattern and necessary geometrical parameters at frequencies from 20 MHz, as the antenna receiving signals at frequency of 2 MHz, will have the sizes, considerably exceeding the dimensions of the car roof.

Although several methods have been developed to detect defective insulation [6–9], there is a problem of missing defective high-voltage insulators when performed by the existing diagnostic methods. The paper proposes to combine the most common optical method of diagnostics by means of an ultraviolet camera installed in a specialized laboratory car with PD and SPD registration by means of antennas, because PD and SPD are the primary electrophysical process determining technical condition of high-voltage insulation. Using two diagnostic techniques (optical and electromagnetic) will increase the reliability of faulty insulation detection, ultimately increasing the probability of detecting sources of interference.

A different solution to this problem is to use GSM-R (GSM Railway) standard, which has been specially developed for railways, in conjunction with equipment included in the European Train Control System, as in European countries, for example. DMR radio standard, which operates at 160 MHz, is also being intensively implemented. DMR, like GSM-R, is less susceptible to interference from electrical equipment than the 2 MHz RRS standard existing in most sections. Mass application of DMR, GSM-R, as well as LTE standards on the networks of “Russian Railways”, OJSC would significantly improve the quality of radio communication, reduce level of interference, but implementation is cost and time effective. At organisation of radio communication on standards GSM-R and DMR there are

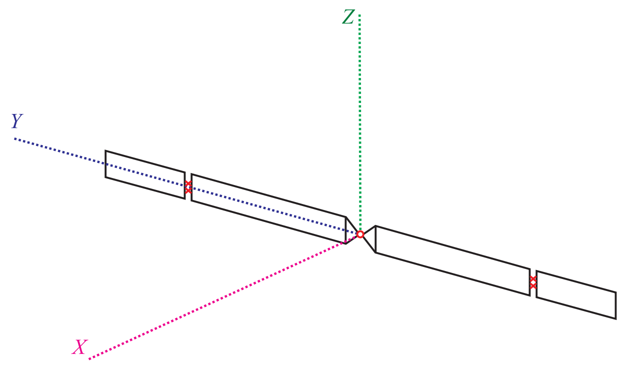


Fig. 1. Appearance of the traveling wave dipole

equipment failures [11, 12], for example, related to interference of waves, demanding equipment reloading.

At indisputable advantages of digital radio communication before analogue radio communication at the present time in operation on a network of "Russian Railways", OJSC there is a RRS working at frequencies of 2.13 and 2.15 MHz. In the following the issues of interference detection in this frequency range will be considered.

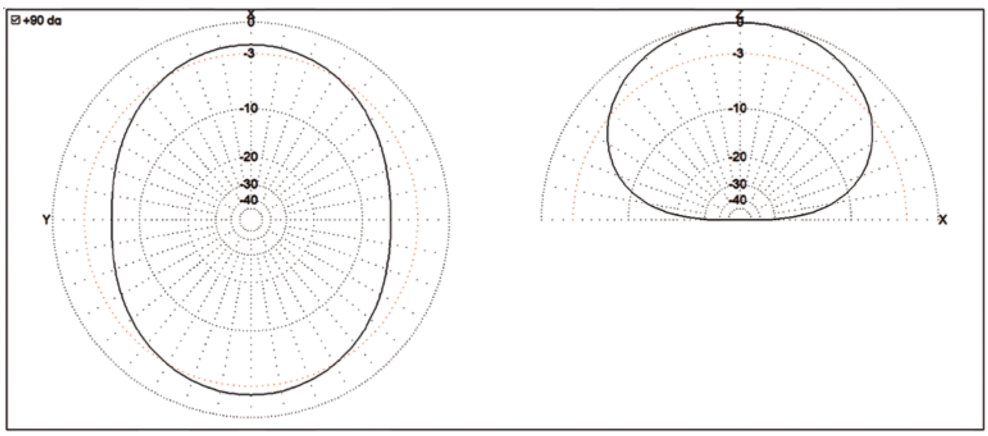
ANTENNA MODELLING

In order to automate and jointly conduct measurements in order to reduce operating costs for diagnostics, it is proposed to locate the recording equipment in the contact network, automation and communication control car. Radio interference caused by insulators and various fittings of the contact network is supposed to be recorded by a digital oscilloscope by means of antennas [5].

It is known that radio interference has an interfering effect on the operation of radio communications in a wide frequency range. Under the influence of such interference fall radio stations operating at frequencies 2.13 and 2.15 MHz. One of the main sources of radio interference are discharges (PD and SPD) arising in the high-voltage insulation of railway contact lines. Generally, PD and SPD are recorded between 1 and 100 MHz, so the antenna has to operate in this frequency range. Previously, a method [13] was proposed to carry out diagnostics by means of electromagnetic registration of signals that occur in the high-voltage line insulation of an AC contact network. This patent defines a method for recording such signals up to 80 MHz. This frequency range is the basis for the further choice of antenna.

As a prototype antenna, a traveling wave dipole designed with MMANA-GAL basic software [14, 15], which operates in the frequency range from 2 to 33 MHz, the appearance is shown in *Fig. 1*. In order to make calculations in MMANA-GAL basic easy, a typical variant was chosen from those proposed in this software product.

The radiation pattern and parameters of the selected travelling wave dipole are shown in *Fig. 2*. All data are shown for a frequency of 3.55 MHz. The choice of frequency is due to the proximity to the operating frequency of RRS — 2.13 and 2.15 MHz.



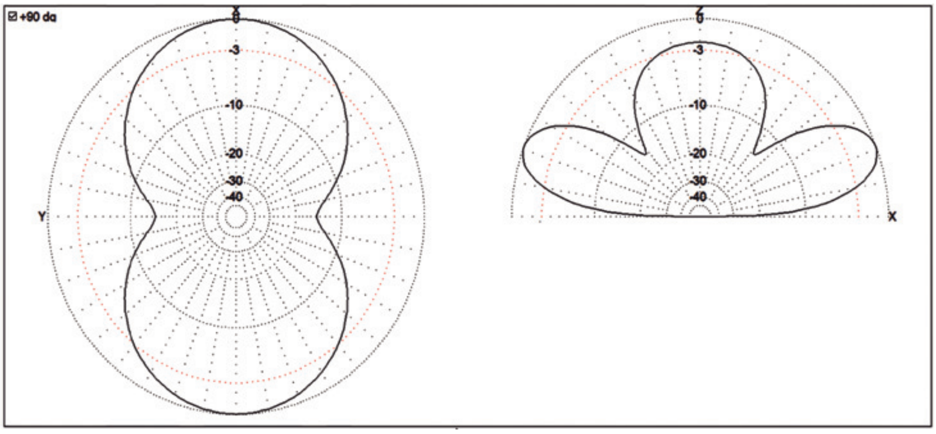
H-polarisation V-polarisation

Ga: 0.18 dBi = 0 dB (H-polarisation); F/B: −1.28 dB; rear azimuth 120 degrees, elevation 60 degrees;

F: 3.550 MHz; Z: 302.171+j161.581 Ohm; SWR: 1.7 (300 Ohm);

Elevation degree: 90.0 degrees (real ground height = 10.00 m); for zenith angle 45.0 degrees, gain = −1.9 dBi

Fig. 2. Radiation pattern and parameters of the traveling wave dipole



H-polarisation V-polarisation

Ga: 1.94 dBi = 0 dB (H-polarisation); F/B: 0.00 dB; rear azimuth 120 degrees, elevation 60 degrees;
F: 20.000 MHz; Z: 219.807-j64.736 Ohm; SWR: 1.5 (300 Ohm);
Elevation degree: 20.9 degrees (real ground height = 10.00 m)

Fig. 3. Antenna radiation pattern after scaling

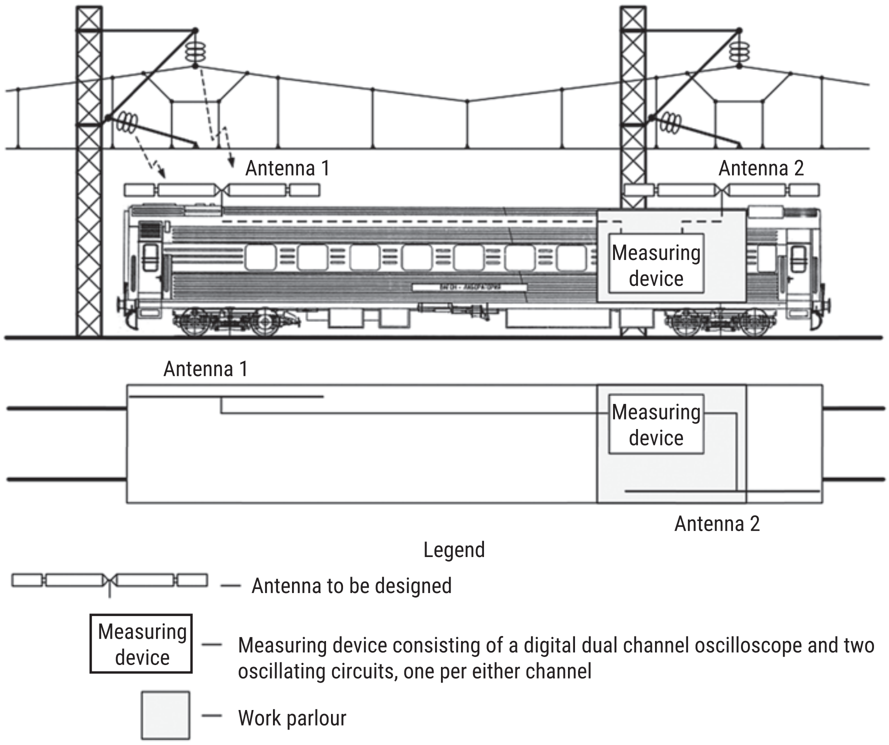


Fig. 4. The layout of the antennas on the roof of the laboratory car

The geometrical dimensions of the antenna (length 700 mm, width 320 mm) in the range from 3 to 33 MHz do not allow placing it on the roof of the laboratory car. It was noted earlier that PD and SPD are recorded in a wide frequency range, so we use the scaling function in the MMANA-GAL basic program, e.g. at 20 MHz. In this case it is necessary to enter a value of 20 MHz in the software, which results in a change in the radiation pattern and a reduction in the size of the antenna, maintaining the correct proportion between the an-

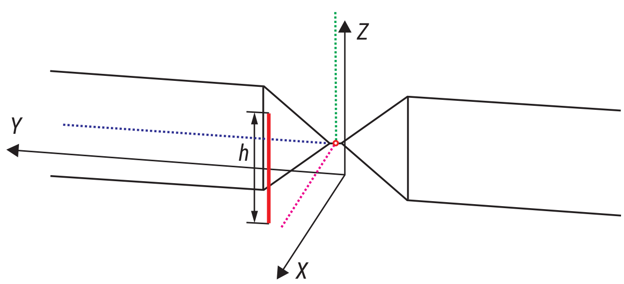
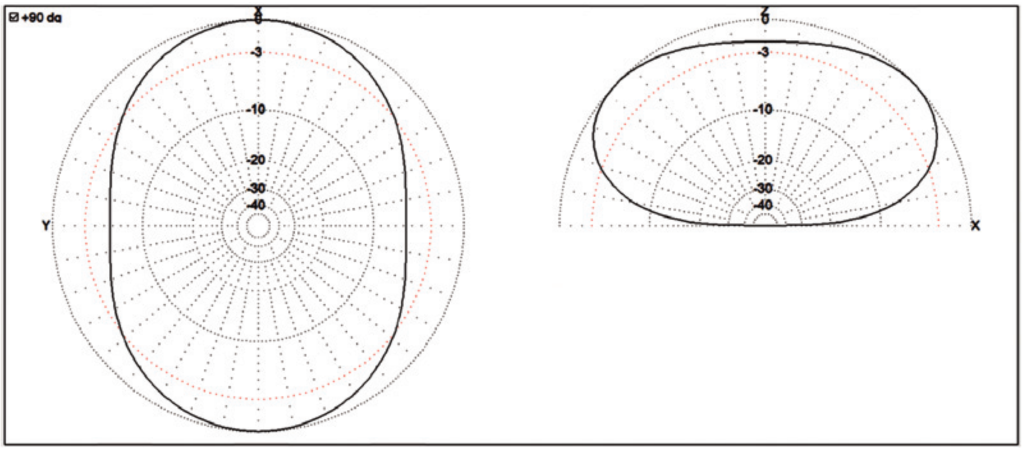


Fig. 5. Determining the antenna width



H-polarisation V-polarisation

Ga: 0.67 dBi = 0 dB (H-polarisation); F/B: 0.00 dB; rear azimuth 120 degrees, elevation 60 degrees;

F: 20.000 MHz; Z: 238.480-j88.112 Ohm; SWR: 1.5 (300 Ohm);

Elevation degree: 43.0 degrees (real ground height = 5 m)

Fig. 6. Antenna radiation pattern at a height of 5 m

tenna elements. *Fig. 3* shows the radiation pattern and parameters of the antenna at 20 MHz.

Next, the height of the antenna to be installed on the roof of the laboratory car must be determined (*Fig. 4*). To do this, set the height of the antenna location in the software.

The mounting height of the antenna should be taken from its width, which is determined by the *Z* coordinate, as shown in *Fig. 5*. The vibrator is located at the origin of the coordinates. The width h of the element highlighted in red is 320 mm.

The height of the antenna is the sum of the following values: height of the laboratory car — 4350 mm; half of the antenna width — 160 mm; height of the antenna installation — 500 mm, provided that the antenna elements do not touch the roof of the car. Total height of antenna location will be 5010 mm. For the calculations in MMANA-GAL basic a height of 5000 mm is assumed. The parameters and the radiation pattern of the antenna at a height of 5000 m are shown in *Fig. 6*.

ANALYSIS OF THE FINDINGS AND CONCLUSIONS

In order to finally determine the working frequency range of the antenna, a study of the standing wave ratio (SWR) in the frequency range from 20 to 70 MHz is required. Using MMANA-GAL basic software product, a plot of SWR versus operating frequency can be plotted (*Fig. 7*).

According to the graph, the SWR varies from 1.25 to 1.5 in the frequency range 20 to 32.5 MHz; from 1.5 to 2 in the frequency range 35 to 67 MHz. Above 67 MHz there is an increase in SWR above 2. From the above parameters, it follows that this antenna satisfies the optimum range of SWR, which is 1.05 to 2 only in the frequency range 20 to 67 MHz.

For further analysis of the antenna pattern variation in the investigated frequency range, it is necessary to study the shape of the radiation pattern in the frequency range from 20 to 70 MHz.

Since, according to the calculated data (*Fig. 8*), there is an increase in the antenna gain relative to the isotropic radiator Ga with increasing frequency, it can

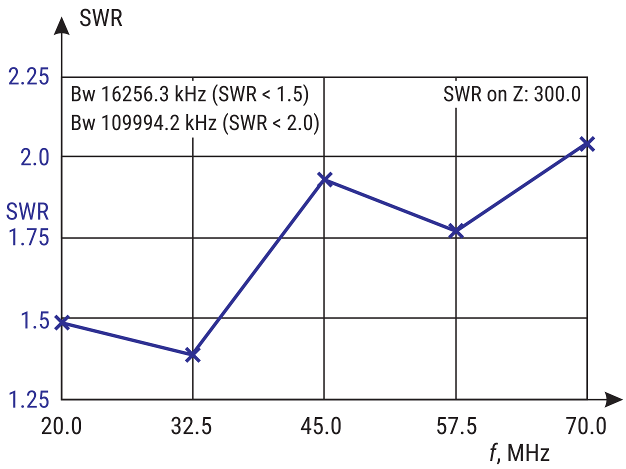
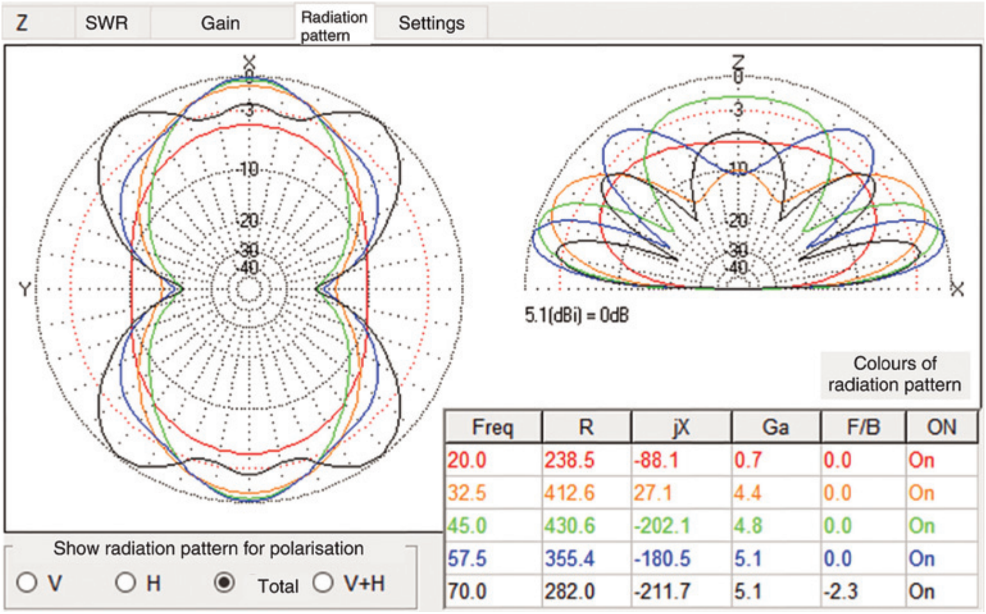


Fig. 7. Graph of the SWR dependence on the operating frequency



Freq	R	jX	Ga	F/B	ON
20.0	238.5	-88.1	0.7	0.0	On
32.5	412.6	27.1	4.4	0.0	On
45.0	430.6	-202.1	4.8	0.0	On
57.5	355.4	-180.5	5.1	0.0	On
70.0	282.0	-211.7	5.1	-2.3	On

Fig. 8. Antenna radiation pattern in the frequency range from 20 to 70 MHz at a height of 5 m

be concluded that the antenna gain improves with increasing frequency.

CONCLUSION

The analysis of the plot of dependence of SWR on operating frequency (*Fig. 7*) and change of antenna gain Ga (*Fig. 8*) allow finally establishing the operating frequency range of the selected antenna — from 20 to 67 MHz.

In order to ensure precise location of the radio interference source it is necessary to place two antennas on the roof of the laboratory car (*Fig. 4*).

Having analysed the radiation patterns of the antennas in *Fig. 6* and *8*, it can be concluded that it is necessary to take it into account when installing the antenna directly on the roof of the laboratory car.

Increased accuracy of measurements is planned to be achieved after conducting additional studies of real sources of radio interference emission. Based on the results of the study, it is assumed that there is a need for additional modelling of antenna parameters, not excluded the correction of its type variant.

Practical application of the antenna will require consideration of the rigidity of the antenna mount and measurement scheme to protect personnel and equipment against induced voltages. In addition, consideration should be given to the referencing of the measurement results to the path coordinate for the location of the radiation source.

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