High voltage pulse sharpening using spiral lines with ferrite

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I. Introduction

In this work we study the operation of a new scheme for high-voltage pulses sharpening, which is the use of a segment of a spiral line with ferrite core located inside of it spiral [4]. The sharpening of the pulse front occurs due to the fact that when a high-voltage pulse passes along the line, a section of the spiral creates axial magnetic field that magnetizes the ferrite. Several configurations of spiral lines are considered and the main regularities for the formation of the shortest duration of the pulse front are discussed.

II. SIMULATION AND THEORY

In this paper, we consider unsaturated ferrite placed inside a spiral central conductor of a coaxial line, as shown in Fig. 1.

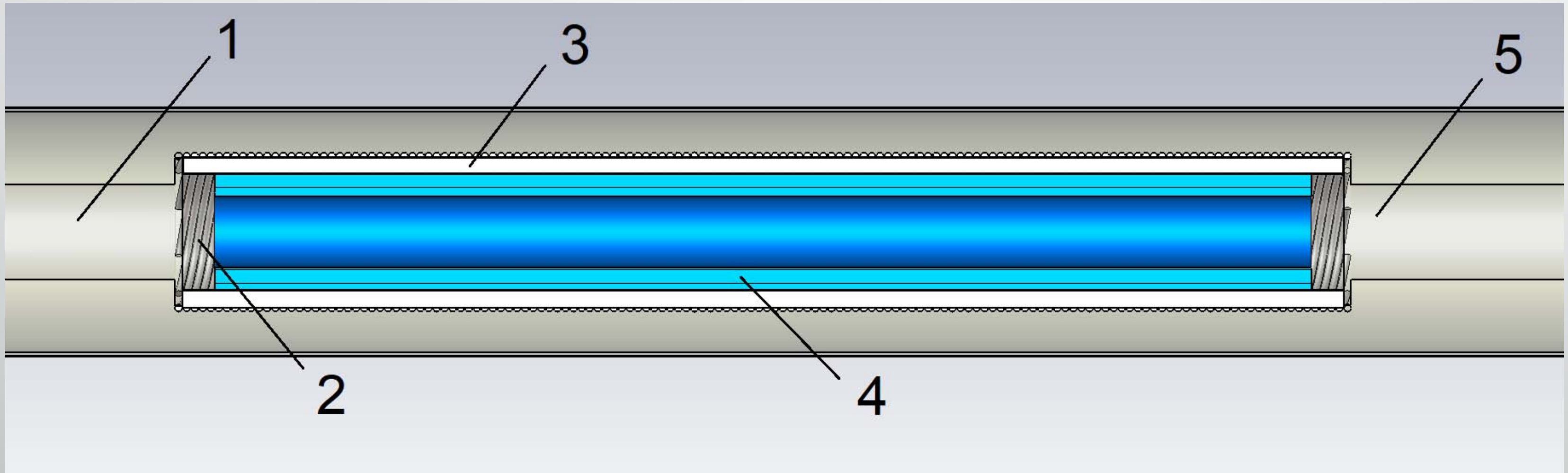

Fig. 1. Geometry of a coaxial line with spiral central conductor with ferrite rings inside the spiral: 1 and 5 – input and output coaxial lines with 38 Ω impedance, 2 – spiral line, 3 – polyamide frame for spiral winding, 4 – ferrite rings

II. SIMULATION AND THEORY

If a high voltage pulse propagates through a quite long transmission line presented in Fig. 1 and saturates ferrite from the remanent magnetization a stationary shock front is formed with a rise time:

$$\tau_r = \frac{1+\alpha^2}{2\alpha\gamma H_z} f\left(m_0\right)$$

$$m_0 = M_r / M_S$$

M_r – remanent magnetization, M_S – saturation magnetization of the ferrite, α – magnetic dissipation parameter, γ – gyromagnetic ratio for electron, H_z – magnetic field strength inside ferrite

II. SIMULATION AND THEORY

The calculated magnetic field distribution for two models of spiral lines is presented in Fig. 2. The first model includes the spiral line with number of coils N = 9 (angle of winding 15.3º), the second – with N = 14.5 (9.6º).

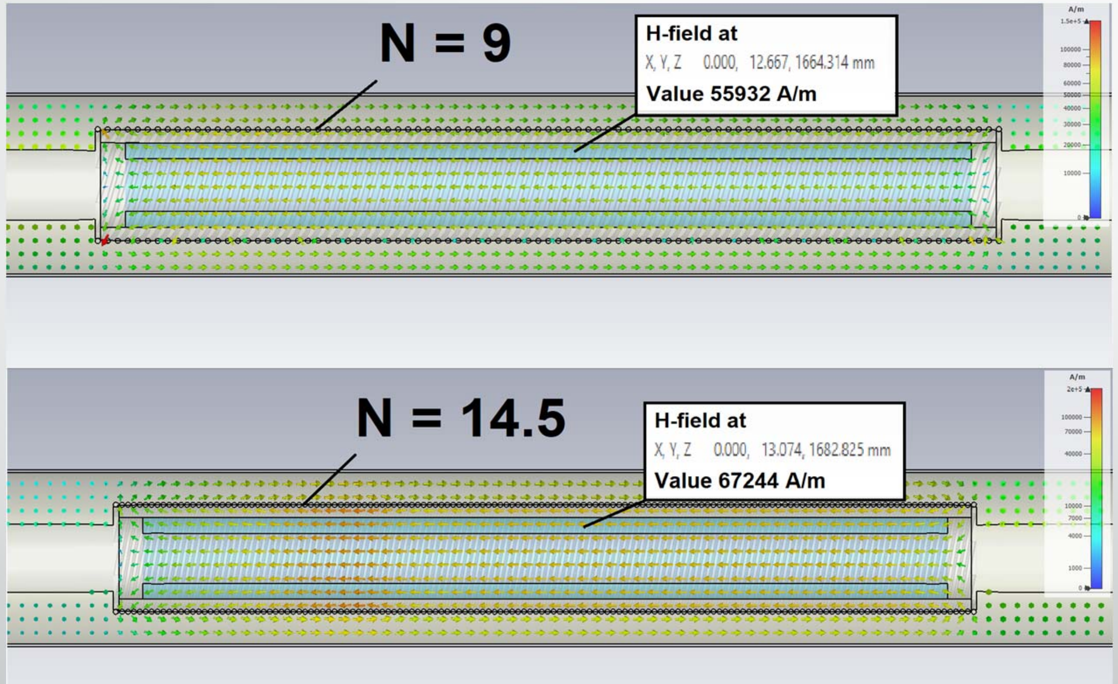

Fig. 2. Magnetic field strength distribution for spiral transmission lines with the number of coils N equal to 9 and 14.5

II. SIMULATION AND THEORY

The waveforms of high voltage pulses at the input and at the output of the spiral lines are presented in Fig. 3 and Fig. 4.

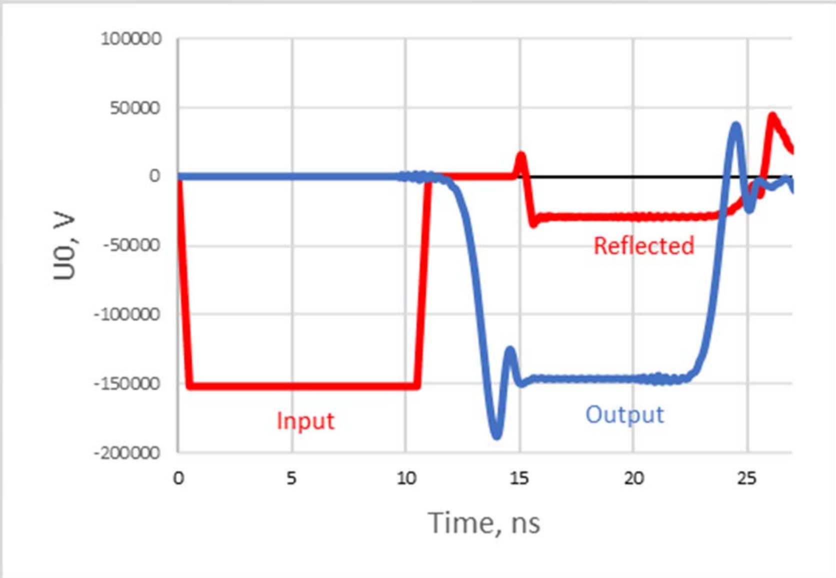

Fig. 3. The waveforms of the incident, reflected and output pulses for the spiral line with number of coils $N = 9$

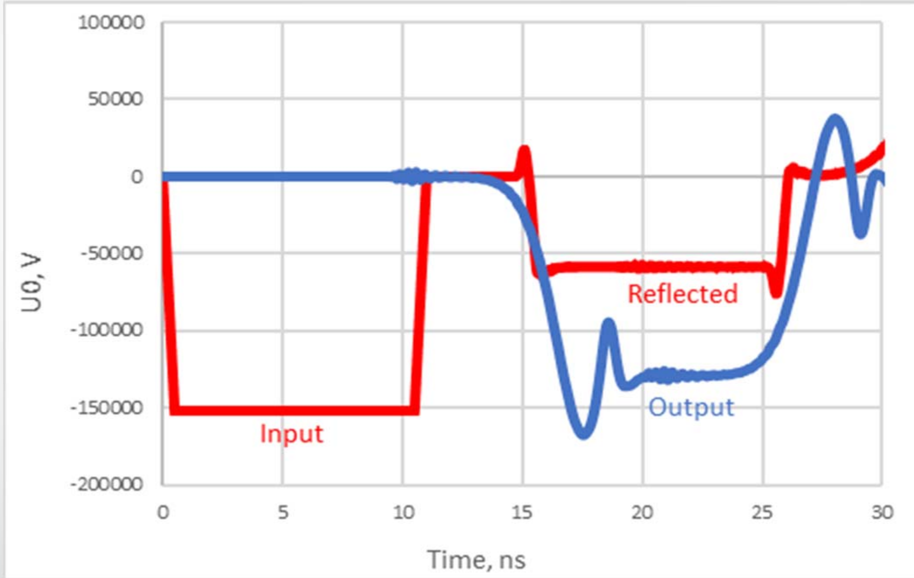

Fig. 4. The waveforms of the incident, reflected and output pulses for the spiral line with number of coils $N = 14.5$

III. EXPERIMENTAL SETUP AND RESULTS

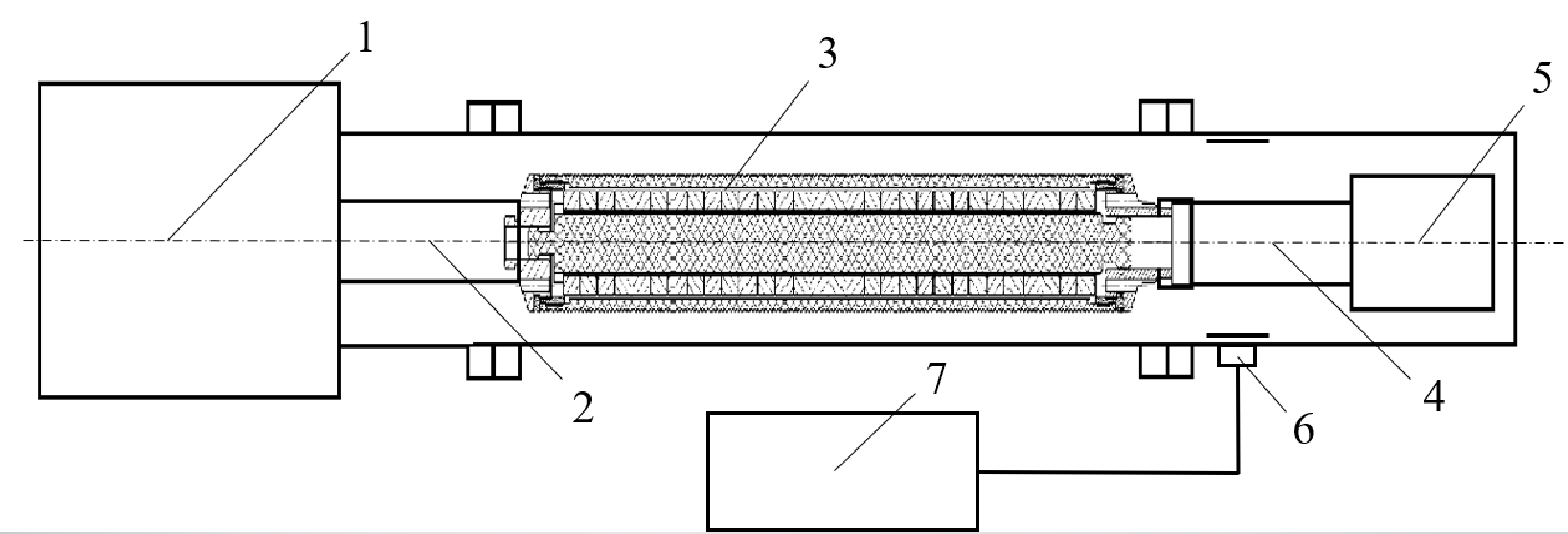

Fig. 5. Diagram of the experimental setup of the spiral line with ferrites: 1 – high voltage driver, 2 and 4 – coaxial transmission lines of 38 Ω, 3 – spiral transmission line with ferrites inside, 5 – resistive of 50 Ω, 6 – capacitive divider, 7 – oscilloscope

III. EXPERIMENTAL SETUP AND RESULTS

The manufactured spiral lines and the ferrite core are shown in Fig. 6.

Fig. 6. Appearance of spiral lines with the number of coils $N = 9$ и 14.5 and the ferrite core

III. EXPERIMENTAL SETUP AND RESULTS

The measured waveforms of the high voltage pulses at the input and at the output of the spiral lines with ferrite core are presented in Fig. 7 and 8.

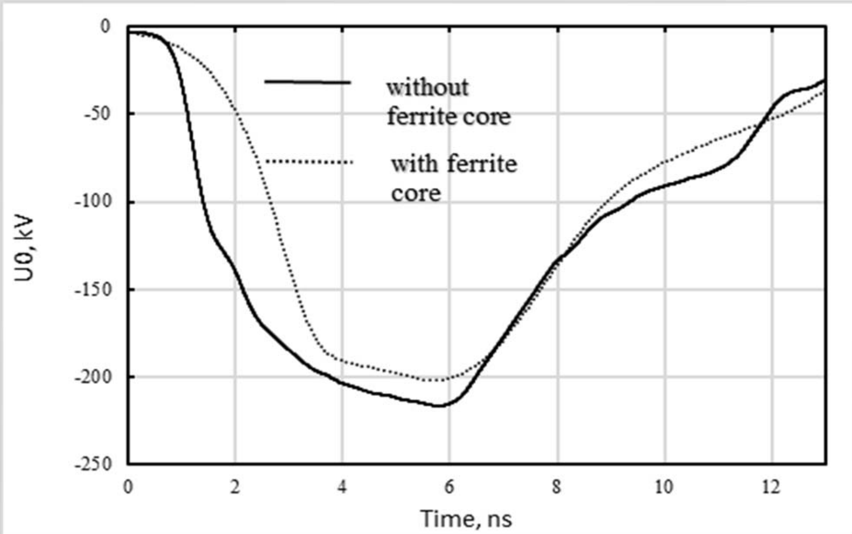

Fig. 7 Waveforms of the high voltage pulses at the output of spiral line with number of coils N = 9 with ferrite core and without it

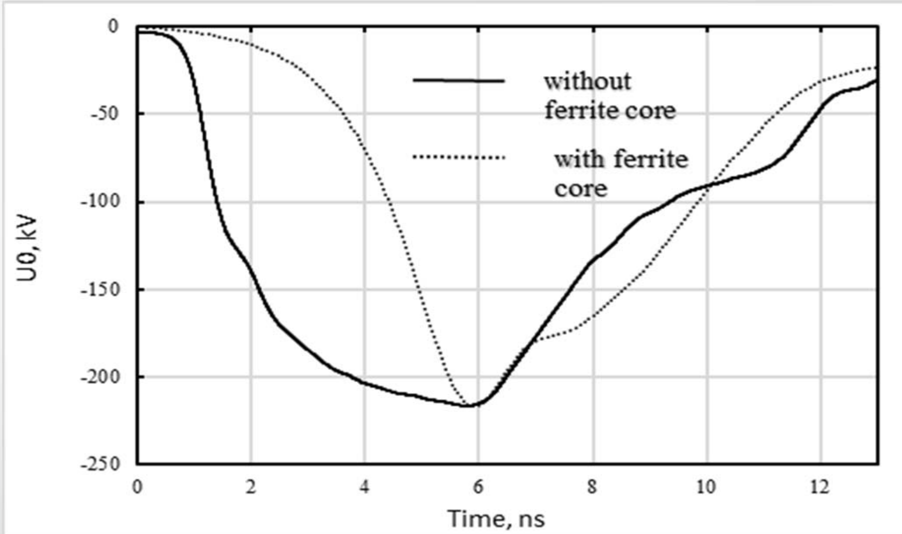

Fig. 8 Waveforms of the high voltage pulses at the output of spiral line with number of coils N = 9 with ferrite core and without it

III. EXPERIMENTAL SETUP AND RESULTS

In our previous experiments we calculated the magnetic losses in 200VNP ferrites depending on the amplitude of the pulsed magnetic field [9]. This dependence recalculated for the cross-section of ferrite rings presented in this paper is shown in Fig. 8 together with the estimation of magnetic losses for spiral lines with 9 and 14.5 coils.

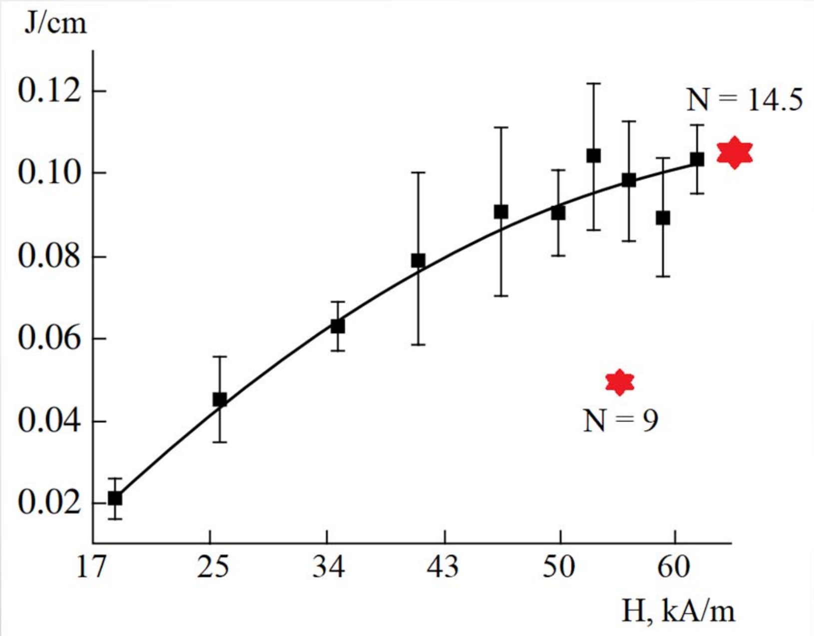

Fig. 9. The dependence of magnetic losses per cm of the transmission line with ferrite on the amplitude of the pulsed magnetic field

[9] K.V. Afanasyev, O.B. Kovalchuk. V.O. Kutenkov, I.V. Romanchenko, V.V. Rostov, “Formation of a subnanosecond front of high-voltage pulses in a coaxial line with unsaturated ferrite”, Instruments and experimental technique, no. 2, pp. 1-5, 2008

IV. DISCUSSION

In this work we have studied high voltage pulse sharpening by a transmission line with spiral central conductor and ferrite core inside it. The initial rise of 2.5 ns of 150 kV pulse was sharpened to 1.7 ns by a spiral with 9 coils and to 1.9 ns by a spiral with 14.5 coils. The theoretical estimation for the amplitude of the pulsed magnetic field in the range 56-67 kA/m is of about 1 ns. The longer rise time obtained in the experiment can be explained by the peculiarity of the energy output from the spiral line with high inductance. In order to get the shorter rise the optimum between the higher magnetic field and higher inductance of the spiral line have to be found. The electrical strength of the system was found to be enough to prevent electrical breakdown.

Thank you!