Example on the suitable condition in theory for application in “new methods on the simplified numerical expression, using peaks $I_p$ in scalar conductive currents of lightning return strokes to the earth $I$, in peaks $B_p$ in the extremely far magnetic fields close to the ground $B$ caused by the lightning return strokes”: Part 1 Short and long wave tails

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Abstract The example on the suitable condition in theory in “terms on rising in wave front of scalar conductive currents $I$” and “effective height of struck grounded large objects $H_i$” for the application in “new methods on the simplified numerical expression, using peaks $I_p$ in scalar conductive currents in the subsequent lightning return strokes to the earth of downward flashes and the first and subsequent lightning return strokes to the earth of upward flashes $I$, in peaks $B_p$ in the extremely far magnetic fields close to the ground $B$ caused by the lightning return strokes” to establishment in probability distribution of the peaks $I_p$ is suggested, in the short and long wave tails in the scalar conductive currents of the lightning return strokes, in trial.

Keywords: lightning parameters, scalar conductive currents, extremely far magnetic fields, subsequent lightning return strokes to the earth of downward flashes, the first and subsequent lightning return strokes to the earth of upward flashes, simplified numerical expression, suitable condition in theory (“terms on rising in wave front of scalar conductive currents” and “effective height of struck grounded large objects”)

1. INTRODUCTION

The establishment on probability distribution of precise lightning parameters stems from the analysis on the characteristics in the electric fields $E$ and magnetic fields $B$ caused by lightning return strokes to the earth has been expected [1]-[7]. Therefore, also with other practical reason, the studies on the “numerical treatment” and “numerical calculation” in the electric fields $E$ and magnetic fields $B$ caused by the lightning return strokes to the earth have been performed as well as the studies on the measurement in the electric fields $E$ and magnetic fields $B$ caused by the lightning return strokes [8]-[23].

On the other hand, in the fundamental studies of the first steps in very recent years in the establishment in probability distribution of precise lightning parameters stems from the analysis in the characteristics in the extremely far electric fields $E$ and magnetic fields $B$ caused by lightning return strokes to the earth, the “new methods on the simplified numerical expression, using peaks $I_p$ in scalar conductive currents of lightning return strokes to the earth $I$, in peaks $E_p$ and $B_p$ in the extremely far electric fields $E$ and magnetic fields close to the ground $B$ caused by the lightning return strokes” with “restriction of usage” have been proposed [15], [16].

In this paper, the result as bases on the “numerical calculation with scientific grounds in waveforms and peaks $\tilde{B}_p$ in the extremely far magnetic fields $\tilde{B}$ caused by the subsequent lightning return strokes to grounded tall structures of downward flashes and the first and subsequent lightning return strokes to grounded tall structures of upward flashes on conventional methods [11], [12]” in the many cases in the condition in the “terms on rising of wave front A-F” and “length of wave tails (short [12] and long [11] wave tails)” in the scalar conductive currents of the vertical lightning return strokes $I$ and the “effective height at lightning points on tops of grounded tall structures $H_i$” is firstly shown. And, due to the “result on numerical calculation with scientific grounds of the peaks $B_p$ in conventional methods” in the many cases of the condition as the bases, the example on the suitable condition in theory in “terms on rising in wave front of scalar conductive currents $I$” and “effective height of struck grounded large objects $H_i$” for the application in “new methods on the simplified numerical expression, using peaks $I_p$ in scalar conductive currents in the subsequent lightning return strokes to the earth of downward flashes and the first and subsequent lightning return strokes to the earth of upward flashes $I$, in peaks $B_p$ in the extremely far magnetic fields close to the ground $B$ caused by the lightning return strokes” to establishment in probability distribution of the peaks $I_p$ is secondly suggested in the short and long wave tails in the scalar conductive currents of the
lightning return strokes, in trial, in order to be smoothly promoted the "comparison to experimental result" and "removal on the restriction of usage" on the fundamental studies of the second steps in very recent years in the establishment in the probability distribution of the peaks \(I_p\) [16] first.

2. REVIEW ON THE METHODS OF CALCULATION USED IN THIS PAPER et al.

2.1 The “numerical calculation with scientific grounds in waveforms and peaks \(B_p\) in the magnetic fields \(B\) caused by the vertical lightning return strokes to grounded tall structures on conventional methods” In this paper, the conventional methods on the numerical calculation with scientific grounds, using the modeling in the “subsequent vertical lightning return strokes to grounded tall structures of downward and upward flashes” and the “first vertical lightning return strokes to grounded tall structures of upward flashes” [16], in the waveforms and peaks \(B_p\) in the magnetic fields \(B\) caused by the vertical lightning return strokes in “velocity on the vertical lightning return strokes to grounded tall structures \(v\)”, “height on bottoms of lightning cloud \(H\)” and “effective height at lightning points on tops of grounded tall structures \(h\)” [11], [12] are used.

2.2 The “new methods on simplified numerical expression in peaks \(B_p\) of the extremely far magnetic fields close to the ground B” The parts on the “new methods on the simplified numerical expression, using peaks \(I_p\) in scalar conductive currents in the subsequent lightning return strokes to the earth of downward flashes and the first and subsequent lightning return strokes to the earth of upward flashes \(I\), in peaks \(B_p\) in the extremely far magnetic fields close to the ground \(B\) caused by the lightning return strokes” with “restriction of usage” proposed in other paper [16] are shown in simplified equations (1)-(3).

\[
B_x = \frac{\mu_0 \nu_c}{2 \pi D} I_x + \frac{\mu_0 \nu_p}{2 \pi D} \beta(v_p) \psi_x, \ldots \ldots \ldots (1)
\]

\[
B_y = \frac{\mu_0 \nu_c}{2 \pi D} \beta(v_c) \psi_y, \ldots \ldots \ldots (2)
\]

\[
B_z = \frac{\mu_0 \nu_p}{2 \pi D} \beta(v_p) \psi_z, \ldots \ldots \ldots (3)
\]

where

- \(I_p\): Peaks on scalar conductive currents of the lightning return strokes to the earth \(I\) almost at particular points \(B\) 1-8 [16]
- \(D\): The positions, horizontally from lightning points, at evaluation points close to the ground \(m\)
- \(v_p\) and \(v_{vp}\): The “extremely high initial velocity” and “extremely high initial vertical velocity” on the lightning return strokes to the earth for the peaks \(I_p\) almost at particular points \(B\) 1 m/s
- \(v_{vp}\) and \(v_{vp}\): The “extremely high velocity” and “extremely high vertical velocity” on the lightning return strokes to the earth for the peaks \(I_p\) almost at particular points \(B\) 3 m/s
- \(\beta(v_p)\) and \(\beta(v_{vp})\): The \(\beta\) function on the special theory of relativity characterized by the “extremely high initial velocity” and “extremely high velocity” in the lightning return strokes to the earth \(v_p\) and \(v_{vp}\) for the peaks \(I_p\) [20]
- \(c_v\): Vertical velocity on vector conductive currents of the lightning return strokes to the earth almost at struck ground objects \(I\) almost at particular points \(B\) 1 m/s
- \(c\): Velocity of light, \(3.0 \times 10^8\) m/s
- \(\mu_0\): Permeability in vacuum, \(1.257 \times 10^{-6}\) H/m

In your interpretation of the simplified equations (1)-(3), please take care for following a couple of technical items [16].

- The bad mixed effect to evaluation points close to the ground on the “time displacement in an instant as assumption of sources” almost at particular points \(B\) 1 and the “time displacement in an instant as assumption on effect of sources” almost at particular points \(B\) 2 and \(B\) 3 may unfortunately strongly disturb upkeeps on precision of the simplified equations (1)-(3).

- The simplified equation (2) is legitimated only for the condition on the good mixed effect to evaluation points close to the ground in the “time displacement in an instant as assumption of sources” almost at particular points \(B\) 1 and the “time displacement in an instant as assumption on effect of sources” almost at particular points \(B\) 2.

In this paper, the example on the suitable condition in theory for application of the simplified equations (1) and (2) is suggested.

2.3 Condition and tools, in this paper, on “numerical calculation with scientific grounds in waveforms and peaks \(B_p\) in the magnetic fields \(B\) caused by the vertical lightning return strokes to grounded tall structures on conventional methods” A summary on the condition and tools, in this paper, in “numerical calculation with scientific grounds in waveforms and peaks \(B_p\) in the magnetic fields \(B\) caused by the vertical lightning return strokes to grounded tall structures on conventional methods [11], [12]” is shown in Table 1. And, the waveforms on the scalar conductive currents in the vertical lightning return strokes to the grounded tall structures in “various terms on rising of wave front \(A-F\)” and “short [12] and long [11] wave tails” 50 kA in peaks \(I\) are shown in Figure 1 (a) and (b), respectively.
Table 1  A summary on the condition and tools, in this paper, in “numerical calculation with scientific grounds in waveforms and peaks $B_p$ in the magnetic fields $B$ caused by the vertical lightning return strokes to grounded tall structures on conventional methods [11], [12]”

<table>
<thead>
<tr>
<th>Items</th>
<th>Condition of numerical calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalar conductive currents along vertical lightning return strokes to grounded tall structures I (refer to Figure 1 (a) and (b))</td>
<td>“Various terms on rising of wave front A-F” and “short [12] and long [11] wave tails”</td>
</tr>
<tr>
<td>Polarity on charge within lower parts of lightning cloud</td>
<td>Negative</td>
</tr>
<tr>
<td>Peaks $I_p$ kA</td>
<td>50</td>
</tr>
<tr>
<td>Velocity on vertical lightning return strokes to grounded tall structures $v$ for the peaks $I_p$ 50 kA/m/s</td>
<td>casually selected $1.2 \times 10^4$</td>
</tr>
<tr>
<td>Height on bottoms of lightning cloud H m [24], [25]</td>
<td>casually selected $1800$</td>
</tr>
<tr>
<td>Effective height at lightning points on tops of grounded tall structures H m</td>
<td>10, 50, 200 and 500</td>
</tr>
<tr>
<td>Evaluation points close to the flat ground in X-y-z Cartesian coordinate system (D, 0, L) m</td>
<td>D 100 k, L 1.5</td>
</tr>
<tr>
<td>The “division on elements of length” and “division on elements of time” on numerical calculation</td>
<td>Division on elements of length $dx$, $dy$ and $dz$ m $5.0 \times 10^{-3}$</td>
</tr>
<tr>
<td>Division on elements of time $dt$ s</td>
<td>$2.5 \times 10^{-9}$</td>
</tr>
<tr>
<td>-Tools of numerical calculation</td>
<td>-Excel-Macro, Visual basic for application (VBA) in Excel on Microsoft office of NEC PC-VY20A/E-5</td>
</tr>
</tbody>
</table>

3. EXAMPLE ON THE SUITABLE CONDITION IN THEORY FOR THE APPLICATION IN “NEW METHODS ON SIMPLIFIED NUMERICAL EXPRESSION IN PEAKS $B_p$ OF THE EXTREMELY FAR MAGNETIC FIELDS CLOSE TO THE GROUND B” TO ESTABLISHMENT IN PROBABILITY DISTRIBUTION OF THE PEAKS $I_p$

3.1 Result as bases on the “numerical calculation with scientific grounds in waveforms and peaks $B_p$ in the magnetic fields $B$ caused by the vertical lightning return strokes to grounded tall structures on conventional methods” in many cases of condition  

The result as bases on the “numerical calculation with scientific grounds in waveforms and peaks $B_p$ in the extremely far magnetic fields $B$ caused by the vertical lightning return strokes to grounded tall structures on conventional methods [11], [12]” in many cases of condition (refer to Table 1) is shown in Figures 2 (a)-(d) and 3 (a)-(d).

3.2 Extraction in trial on the example in the suitable condition in theory due to “result on numerical calculation with scientific grounds of the peaks $B_p$ in conventional methods” as bases 

The example on the suitable condition in theory due to “result on numerical calculation with scientific grounds of the peaks $B_p$ in conventional methods” as bases for the application in “new methods on simplified numerical expression in peaks $B_p$ of the extremely far magnetic fields close to the ground B (refer to simplified equations (1) and (2)) [16]” to establishment in probability distribution of the peaks $I_p$ is suggested, in trial, in Table 2.
Figure 2 Result as bases on "numerical calculation with scientific grounds in waveforms and peaks \( B_p \) in the magnetic fields \( B \) caused by the vertical lightning return strokes to grounded tall structures of short wave tails on conventional methods" (refer to Table 1 on condition of numerical calculation)

In the acceptable criterions in the 80 %–120 % value in "result on calculation of the peaks \( B_p \) with simplified equations (1) and (2)", the “result on numerical calculation with scientific grounds of the peaks \( B_p \) in conventional methods” on the “A and B of Figures 2 (b) and 3 (b)”, “C and D of Figures 2 (c) and 3 (c)”, “B of Figure 3 (c)” and “D-F of Figures 2 (d) and 3 (d)” unfortunately ranges over the value expressed by simplified inequality (4) stems from bad mixed effect to evaluation points close to the ground [16] (refer to section 2.2).

\[
\frac{\mu_0 \nu_{\alpha}}{2 \pi R} \rho_{(\nu)} y_j < B_p < \frac{\mu_0 \nu_{\beta}}{2 \pi R} i + \frac{\mu_0 \nu_{\alpha}}{2 \pi R} \rho_{(\nu)} y_j \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (4)
\]

Corresponding to the origins in the relaxation points of vector conductive currents \( \mathbf{i} \) within lower parts of lightning cloud (particular points B 3), the “every result on numerical calculation of the expected second peaks \( B_p \)” on the condition of the numerical calculation in this paper (refer to Table 1) is smaller than, even on cases of short wave tails in the Figure 2 (a)-(d) as well as on the cases of long wave tails in the Figure 3 (a)-(d), the 80 % value on “result on calculation of the peaks \( B_p \) with simplified equation (3)” stems from bad mixed effect to evaluation points close to the ground [16] (refer to section 2.2).
In this way, as suggested in the Table 2, the example on the suitable condition in theory in “terms on rising in wave front of scalar conductive currents I” and “effective height of struck grounded large objects H_i” for the application in “new methods on simplified numerical expression in peaks B_p of the extremely far magnetic fields close to the ground B (refer to simplified equations (1) and (2)) to establishment in probability distribution of the peaks I_p is able to be extracted in trial, referring to the example on the suitable condition in the theory due to “result on numerical calculation with scientific grounds of the peaks B_p in conventional methods” as bases, from the condition for the result of the numerical calculation shown in the Figures 2 (a)-(d) and 3 (a)-(d).

4. CONCLUSIONS

Due to the result on the “numerical calculation with scientific grounds in waveforms and peaks B_p in the magnetic fields B caused by the vertical lightning return strokes to grounded tall structures on conventional methods [11], [12]” in many cases of condition (refer to Table 1) as bases, the example
Table 2 Example on the suitable condition in theory due to “result on numerical calculation with scientific grounds of the peaks Bp in conventional methods” as bases for application in “new methods on simplified numerical expression in peaks Bp of the extremely far magnetic fields close to the ground B”

<table>
<thead>
<tr>
<th>Calculation with simplified equations [16] (refer to section 2.2 and Note A)</th>
<th>Suitable condition in theory due to “result on numerical calculation with scientific grounds of the peaks Bp in conventional methods” as bases for the application</th>
<th>Numerical calculation [11], [12] (refer to sections 2.1 and 3.1 and Table 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified equation (1)</td>
<td>Result on calculation of the peaks Bp T</td>
<td>A and B in Figure 2 (c)</td>
</tr>
<tr>
<td></td>
<td>1.15 (80 %)-1.44-1.72 (120 %) × 10^7</td>
<td>1.44 and 1.16 × 10^7</td>
</tr>
<tr>
<td></td>
<td>A, B and C in Figure 2 (d)</td>
<td>1.44,1.44 and 1.31 × 10^7</td>
</tr>
<tr>
<td></td>
<td>A of Figure 3 (e)</td>
<td>1.44 × 10^7</td>
</tr>
<tr>
<td></td>
<td>A, B and C in Figure 3 (f)</td>
<td>1.44, 1.43 and 1.24 × 10^7</td>
</tr>
<tr>
<td>Simplified equation (2)</td>
<td>Result on calculation of the peaks Bp T</td>
<td>A-F in Figure 2 (a)</td>
</tr>
<tr>
<td></td>
<td>3.49 (80 %)-4.37-5.24 (120 %) × 10^8</td>
<td>4.86, 4.38, 4.39, 4.39, 4.41 and 4.42 × 10^8</td>
</tr>
<tr>
<td></td>
<td>C-F in Figure 2 (b)</td>
<td>4.62, 4.46, 4.44 and 4.44 × 10^8</td>
</tr>
<tr>
<td></td>
<td>E and F in Figure 2 (c)</td>
<td>5.09 and 4.81 × 10^8</td>
</tr>
<tr>
<td></td>
<td>A-F in Figure 3 (a)</td>
<td>4.78, 4.38, 4.39, 4.41 and 4.43 × 10^8</td>
</tr>
<tr>
<td></td>
<td>C-F in Figure 3 (b)</td>
<td>4.44, 4.42, 4.44 and 4.44 × 10^8</td>
</tr>
<tr>
<td></td>
<td>E and F in Figure 3 (c)</td>
<td>4.67 and 4.53 × 10^8</td>
</tr>
</tbody>
</table>

Note:
- The “result on calculation of the peaks Bp with simplified equations (1) and (2)” and “result on numerical calculation with scientific grounds of the peaks Bp in conventional methods” in this Table are indicated as absolute value.
- The positions, horizontally from lightning points, at evaluation points close to the ground D are 100 km.
- The “extremely high initial vertical velocity v0” and “extremely high initial vertical velocity v0” almost at particular points B and 1 and the “extremely high initial vertical velocity v0” and “extremely high vertical velocity v0” almost at particular points B 3 on lightning return strokes to the earth for the peaks I (16) are casually selected, all over, as 1.2 × 10^7 m/s.
- In the condition in the “numerical calculation of the expected second peaks Bp for almost at particular points B 3 in this paper (refer to Table 1 and Figure 1 (a) and (b)), as suggested in the Figures 2 and 3, there is not, at all, the example on the suitable condition in theory due to “result on numerical calculation of the expected second peaks Bp” as bases for the acceptable criterions on 80 %-120 % (3.49 (80 %)-4.37-5.24 (120 %) × 10^-8 T) value in “result on calculation of the peaks Bp with simplified equation (3) [16].”

Note A:
- In the extraction in trail in the example in the suitable condition in theory due to “result on numerical calculation with scientific grounds of the peaks Bp in conventional methods”, as bases for the application, the 80 %-120 % value on “result on calculation of the peaks Bp with simplified equations (1) and (2)” is selected as acceptable criterions.

on the suitable condition in theory in “terms on rising in wave front of scalar conductive currents I” and “effective height of struck grounded large objects H,” for the application in “new methods on the simplified numerical expression, using peaks Ip in scalar conductive currents in the subsequent lightning return strokes to the earth of downward flashes and the first and subsequent lightning return strokes to the earth of upward flashes I, in peaks Bp in the extremely far magnetic fields close to the ground B caused by the lightning return strokes (refer to simplified equations (1) and (2))” to establishment in probability distribution of the peaks Ip is suggested in the short and long waive tails in the scalar conductive currents of the lightning return strokes, in trial, in order to be smoothly promoted the “comparison to experimental result” and “removal on the restriction of usage” on the fundamental studies of the second steps in very recent years in the establishment in the probability distribution of the peaks Ip [16] first.

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