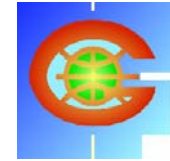
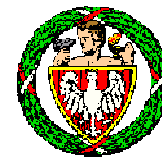


# **ELECTRIC FIELD SIGNATURES OF RETURN STROKES IN CG LIGHTNING FLASHES RECORDED DURING SUMMER 2005 IN POLAND**

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## OBJECTIVES OF ELECTRIC FIELD CHANGE ( $\Delta E$ ) MEASUREMENTS DURING LIGHTNING DISCHARGE (CG or IC&CG)

- Records of  $\Delta E$  waveform signatures with high time resolution (25 MS/s) in digital form,
- Determination of  $\Delta E$  main time parameters - rise time ( $t_r$ ) and the decay time ( $t_d$ ) of all collected RS waveforms,
- Denoting characteristic features of particular RS waveform – the “ $\gamma$ -peaks” for rise stage of  $\Delta E$  and secondary or subsidiary peaks for decay stage of  $\Delta E$ ,
- Comparing the obtained time characteristics of  $\Delta E$  of particular RS with detected CG lightning flashes data by SAFIR network system in Poland

# DATA ACQUISITION SYSTEM

- Gives possibility to collect signatures of RS waveform for CG flashes located in the range of app. 50 km from measuring point and
- Consists of:
  - 2 LF antennas,
    - one PAD 04 unit with charge amplifier AD 825 (the same as used by SAFIR system for CG flash discrimination), frequency band 300 Hz - 3MHz, feedback time constant  $\tau = 6.7$  ms;
    - the second antenna - AD 711 with charge amplifier having frequency band - 20 Hz to 1.3 MHz, and feedback time constant  $\tau = 5$  ms,
    - 2 channel AD PC 12-bit card, having 64 MB memory buffer in each channel, triggered by  $(\partial E/\partial t)$  pulse obtained from external Maxwell current antenna with own programme package (LATECH trade mark) for archiving and visualization of collected data
  - the GPS time module unit for time stamping the same as used by SAFIR system

**Antenna LF – PAD 04 (AD 825)**





**Antenna LF – AD 711**

**Maxwell current antenna**

# EXAMPLES OF RS WAVEFORM SIGNATURES

Description of recorded E field waveforms:

- Convention of E polarity determination for PAD 04 (SAFIR) records:
  - bottom record: the electric field is taken as positive, if there are positive charges aloft and when move downwards to the Earth surface (atmospheric electricity sign),
- Convention of E polarity determination for LF sensor (AD 711) records:
  - upper record: „physics” sign (opposite polarity of E to the bottom record).

# INFORMATION ON COLLECTED DATABASE OF RS<sub>+</sub> AND RS<sub>-</sub> WAVEFORM SIGNATURES

## ***15.06.05 (from 14:24:01 to 16:12:59 LT, i.e., for period $\Delta t=1^h48^m02^s$ ):***

- 9×RS<sub>-</sub> records from reference measuring point; 5 of them have their E field amplitude without signal cutting off due to improper selection of amplifier gain
- For that data subset only 3×RS<sub>-</sub> simultaneous records were detected by the SAFIR system

## ***07.07.05 (from 14:01:57 to 15:20:29 LT, i.e., for period $\Delta t=1^h18^m32^s$ ):***

- 7×RS<sub>-</sub> records from reference measuring point; 2 of them have their E field amplitude without signal cutting off due to improper selection of amplifier gain
- For that data subset only 6×RS<sub>-</sub> were simultaneously detected by the SAFIR system

## ***12.09.05 (from 15:24:35 to 18:12:11 LT, i.e., for period $\Delta t=2^h46^m59^s$ ):***

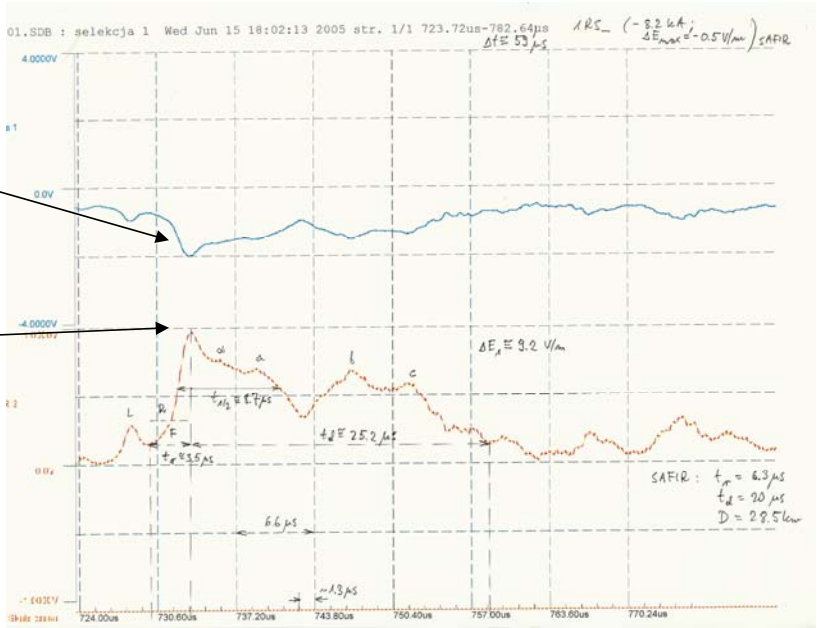
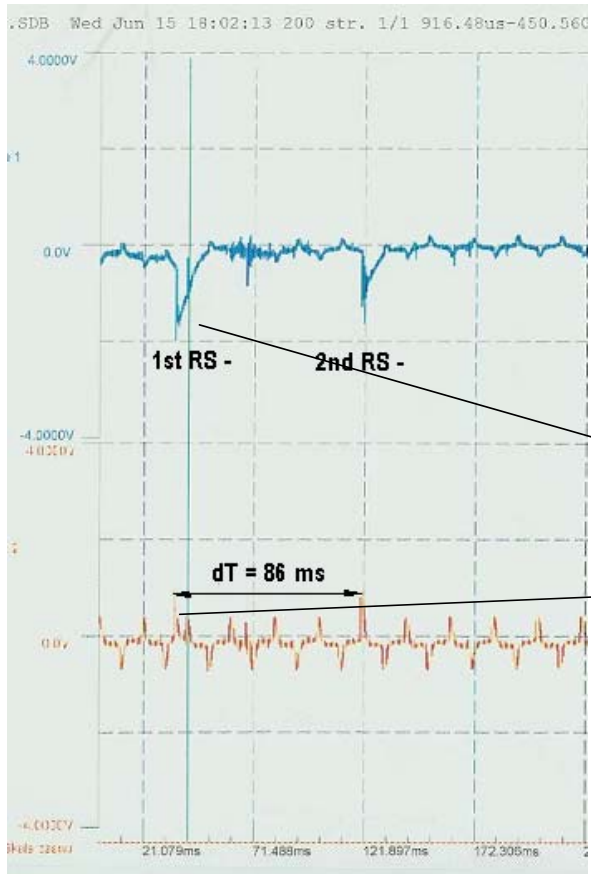
- 2×RS<sub>+</sub> and 7×RS<sub>-</sub> (with 7×RS<sub>-</sub> having full signal amplitude) were detected from IGF reference measuring point
- For that data subset the SAFIR simultaneous detections resulted in 2× RS<sub>+</sub> and 11×RS<sub>-</sub> events; more RS<sub>-</sub> cases were recorded by SAFIR than reference measurements, i.e., that some of RS were misidentified by SAFIR

# EXAMPLES OF RS WAVEFORM RECORDS

Records on 15.06.05 – Case 1

2 RS- ; 1st detected simultaneously by SAFIR  
in distance of 28,5 km from measuring point,

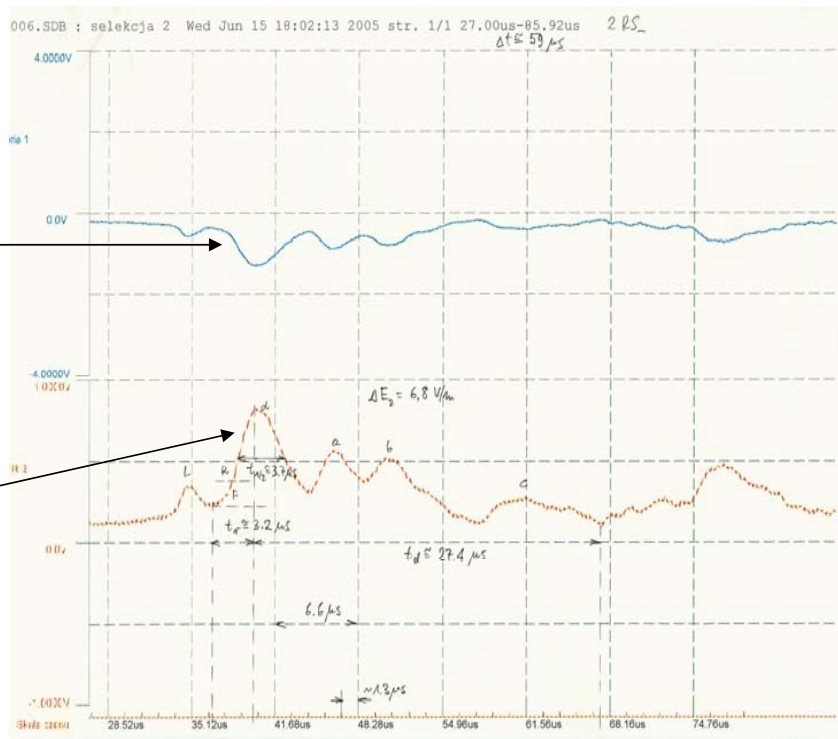
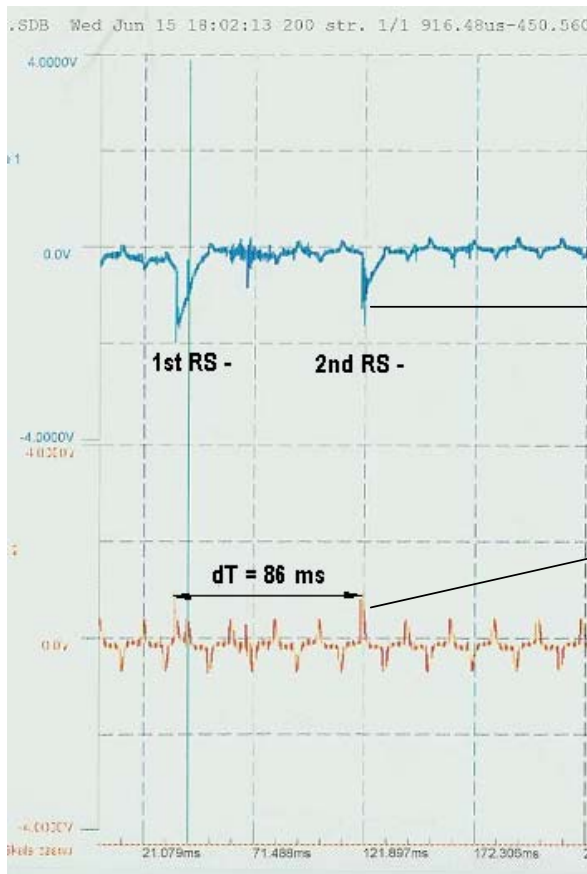
$$I_m = - 8,2 \text{ kA}$$



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 15.06.05 – Case 1

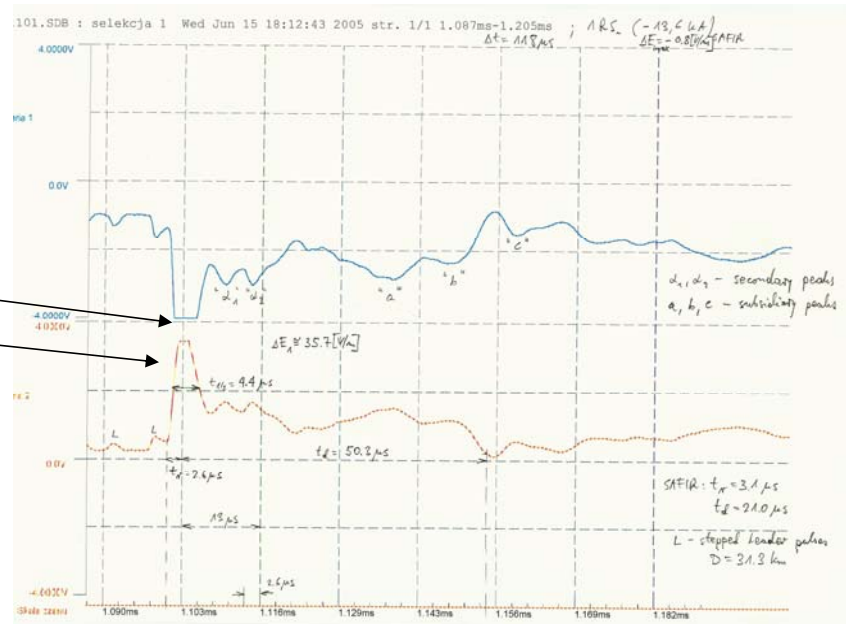
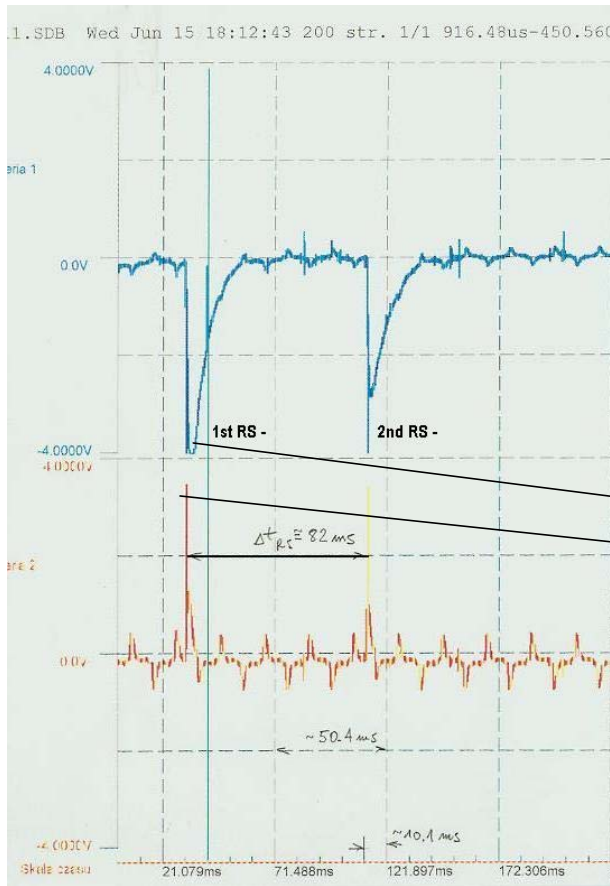
2 RS- ; 2-nd RS not detected by SAFIR



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 15.06.05 – Case 2

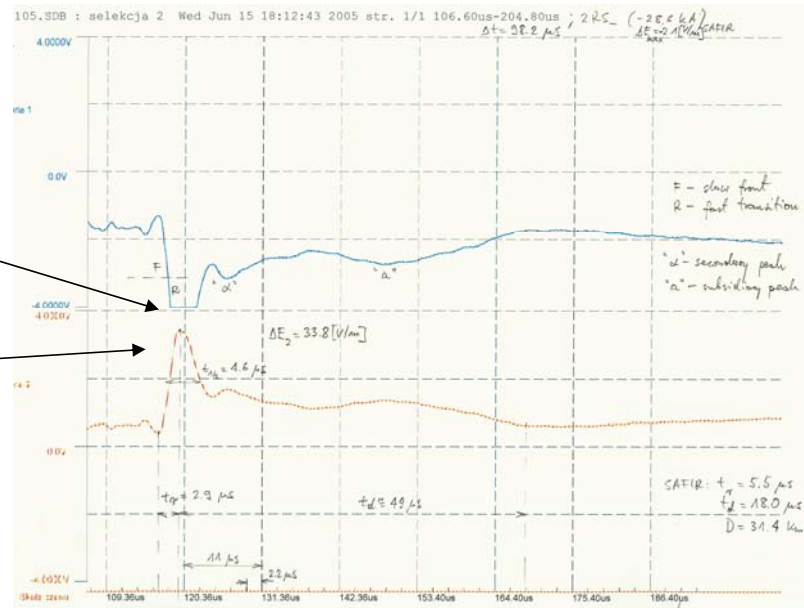
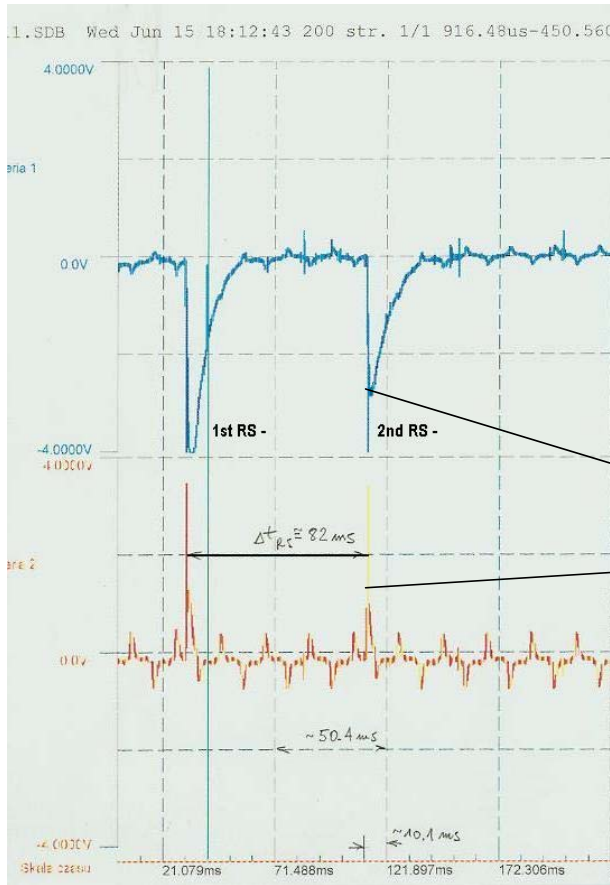
2 RS- ; both detected simultaneously by SAFIR  
 distance of  $d_1 = 31,3$  km,  $d_2 = 31,4$  km from  
 measuring point,  $I_{1m} = - 13,6$  kA,  $I_{2m} = - 28,6$  kA



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 15.06.05 – Case 2

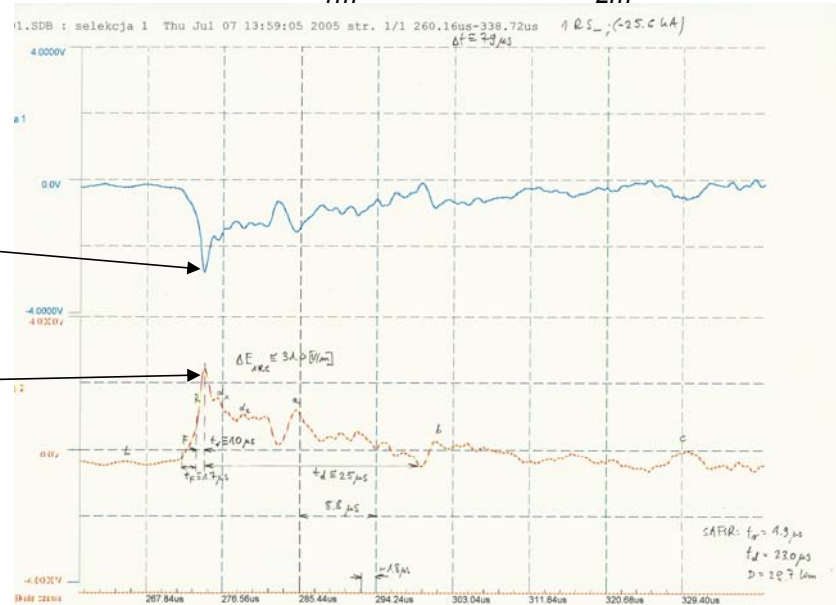
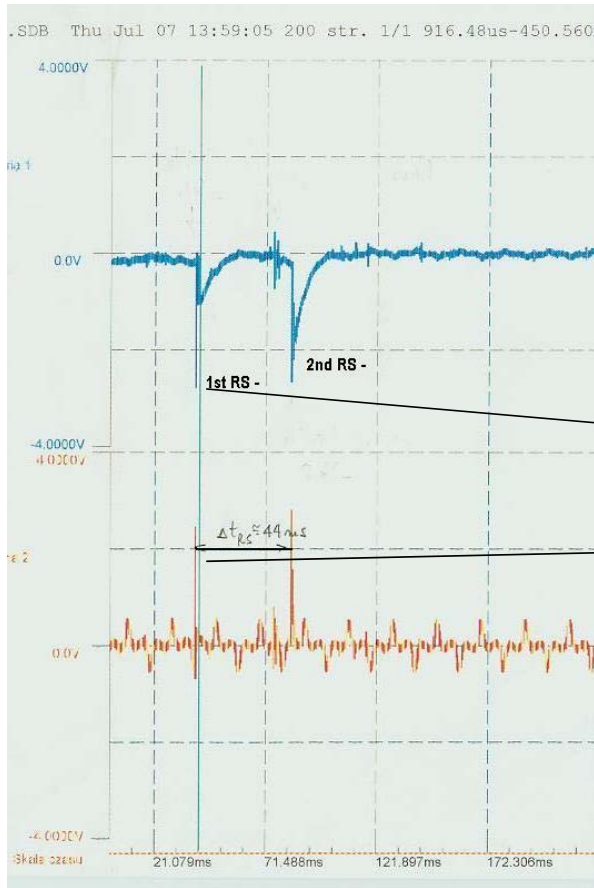
2 RS - ; both detected simultaneously by SAFIR  
 distance of  $d_1 = 31,3$  km,  $d_2 = 31,4$  km from  
 measuring point,  $I_{1m} = - 13,6$  kA,  $I_{2m} = - 28,6$  kA



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 7.07.05.

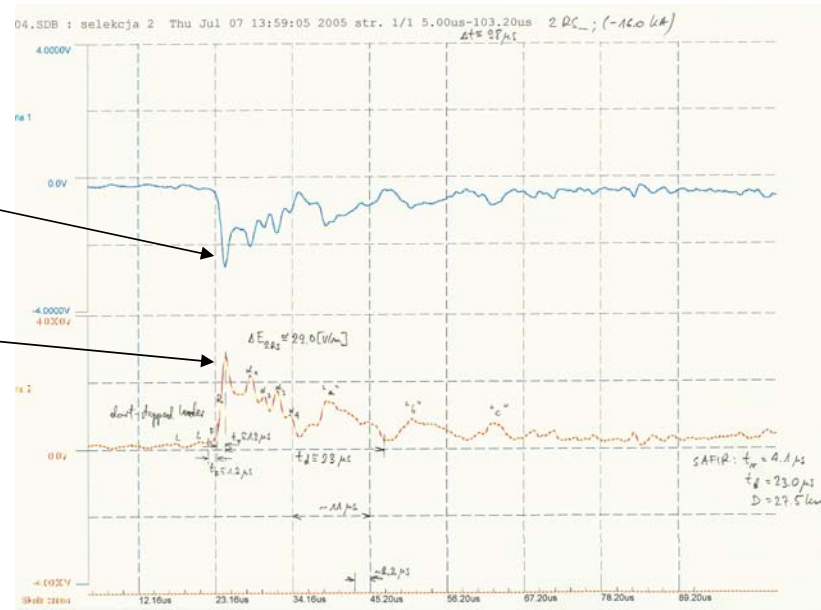
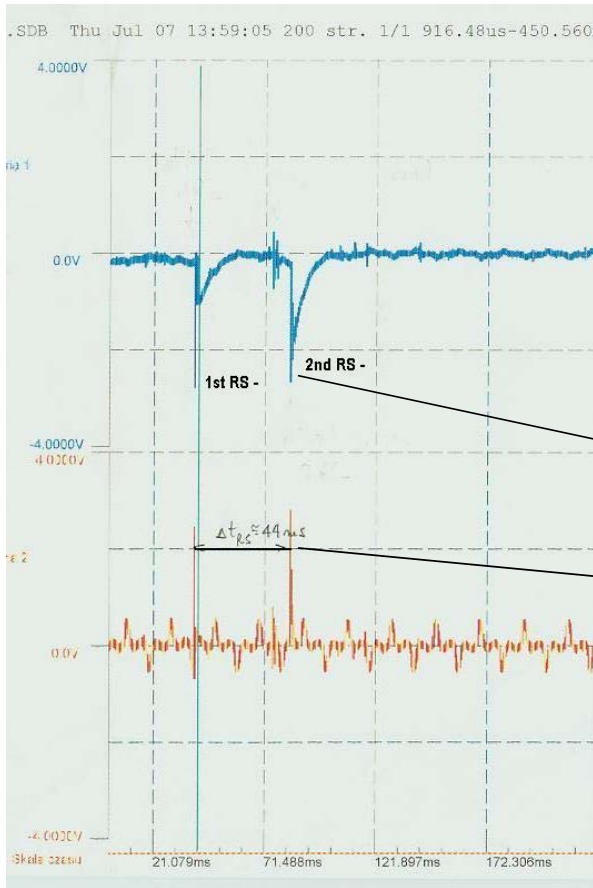
2 RS- ; both detected simultaneously by SAFIR distance of  $d_1 = 29,7$  km,  $d_2 = 27,5$  km from measuring point,  $I_{1m} = -25,6$  kA,  $I_{2m} = -16,0$  kA



# EXAMPLES OF RS WAVEFORM RECORDS

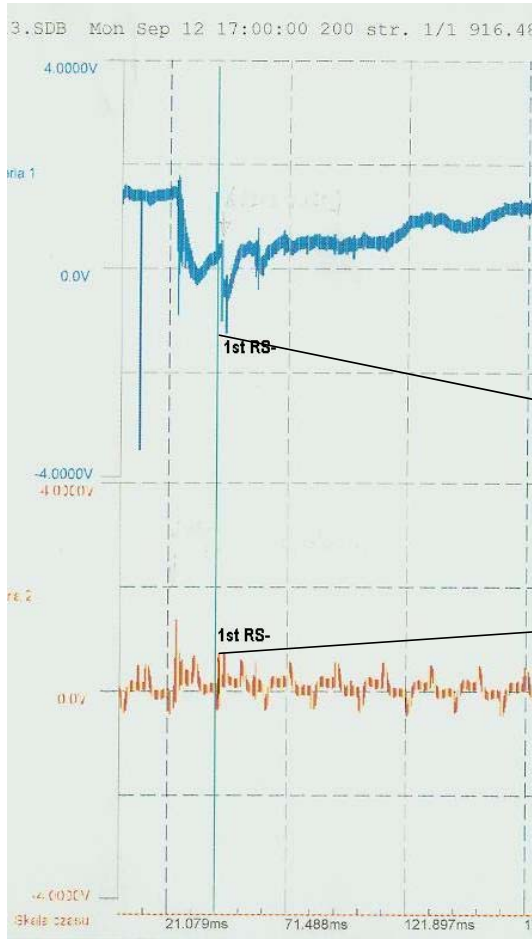
Records on 7.07.05.

2 RS- ; both detected simultaneously by SAFIR distance of  $d_1 = 29,7$  km,  $d_2 = 27,5$  km from measuring point,  $I_{1m} = - 25,6$  kA,  $I_{2m} = - 16,0$  kA

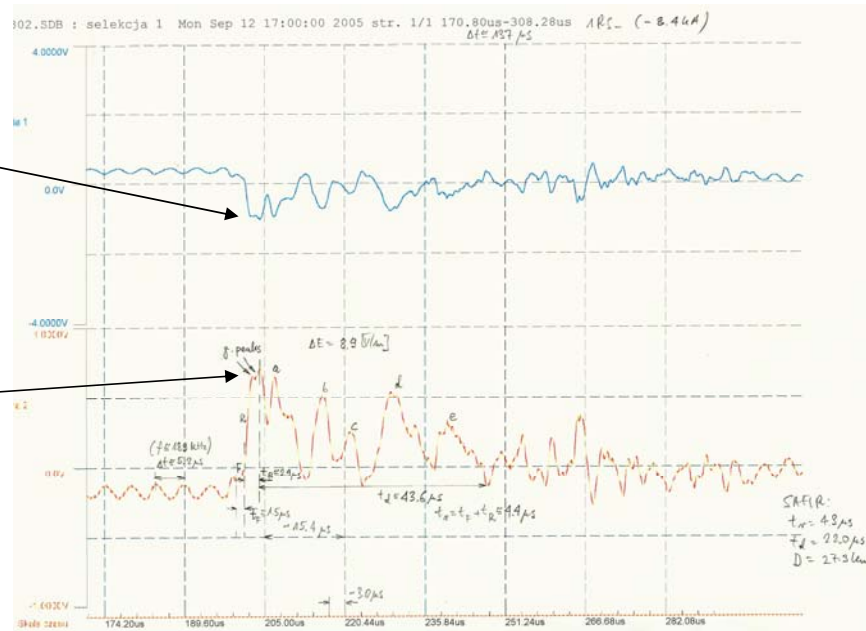




# EXAMPLES OF RS WAVEFORM RECORDS



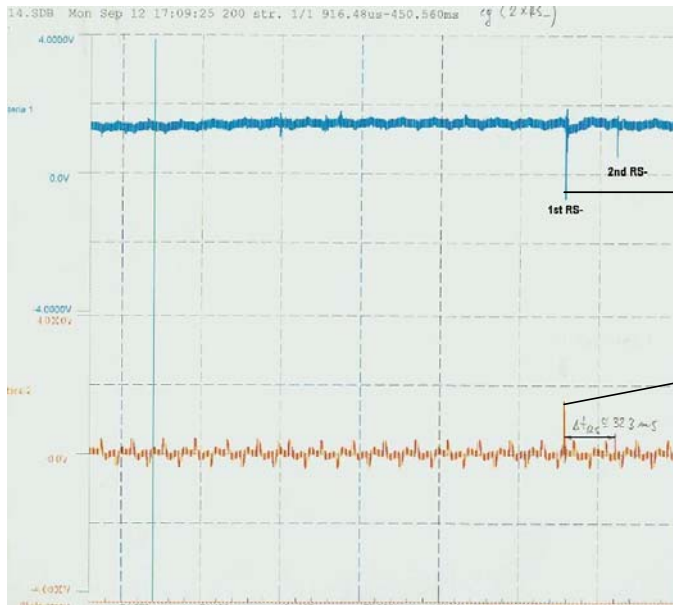
Records on 12.09.05. – Case 2  
 1RS-; detected simultaneously by SAFIR  
 distance of  $d = 27,3$  km, from measuring point,  
 $I_{1m} = -8,4$  kA



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 12.09.05. – Case 3

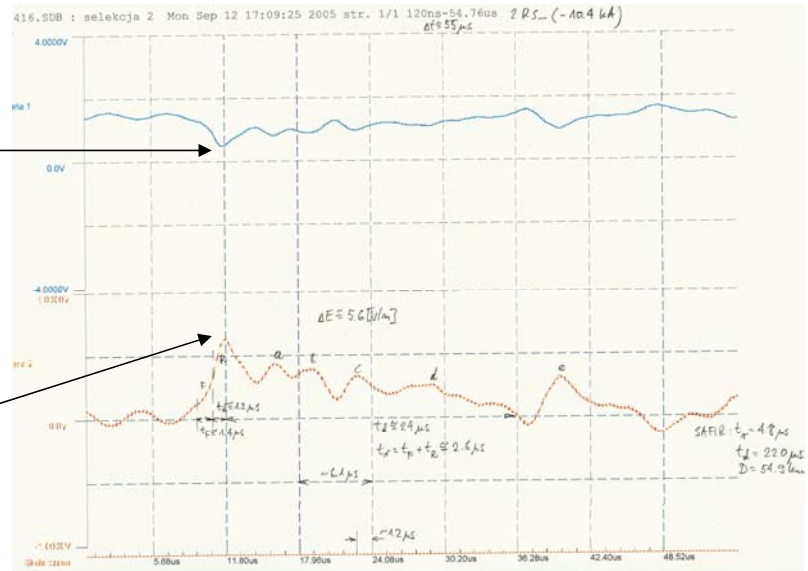
2 RS-; detected simultaneously by SAFIR distance of  $d_1 = 55,8$  km,  $d_2 = 54,9$  km from measuring point,  $I_{1m} = -22,9$  kA,  $I_{2m} = -10,4$  kA



# EXAMPLES OF RS WAVEFORM RECORDS

Records on 12.09.05. – Case 3

2 RS-; detected simultaneously by SAFIR distance of  $d_1 = 55,8$  km,  $d_2 = 54,9$  km from measuring point,  $I_{1m} = -22,9$  kA,  $I_{2m} = -10,4$  kA



# CONCLUSIONS

- It was found that during the fast transition phase of RS additional structures have been appeared, similar to those observed in Florida (USA) and called by Murray et al. (2005) as „ $\gamma$ -peaks”,
- For 16 distinguished cases of the first return stroke transferring negative charge to ground (1RS<sub>-</sub>), the mean rise time ( $t_r$ ) of their waveforms was equal to  $(2.9 \pm 0.6) \mu\text{s}$  and their mean decay time ( $t_d$ ) was equal to  $(32.2 \pm 29.2) \mu\text{s}$ , whereas the mean number of their secondary and subsidiary impulses was equal to  $3.9 \pm 1.4$ ,
- For 8 distinguished cases of the second return strokes transferring also negative charge to ground (2RS<sub>-</sub>) were measured:  $\langle t_r \rangle = (3.3 \pm 0.9) \mu\text{s}$  and  $\langle t_d \rangle = (29.5 \pm 12.6) \mu\text{s}$  while the mean number of their secondary and subsidiary impulses was equal to  $3.6 \pm 1.5$ ,
- For 2 distinguished cases of the first return strokes transferring positive charge to ground (1RS<sub>+</sub>),  $\langle t_r \rangle = 0.7 \mu\text{s}$  and  $\langle t_d \rangle = (6.8 \pm 1.7) \mu\text{s}$ , and the mean number of their secondary and subsidiary peaks was equal to 5,
- Comparison of SAFIR data and data from reference measurement point have shown that for analysed cases the values of  $\langle t_r \rangle$  are overestimated while values of  $\langle t_d \rangle$  are underestimated.

THANK YOU FOR YOUR ATTENTION !

QUESTIONS ?