

Window sensor for the lightning current measurements

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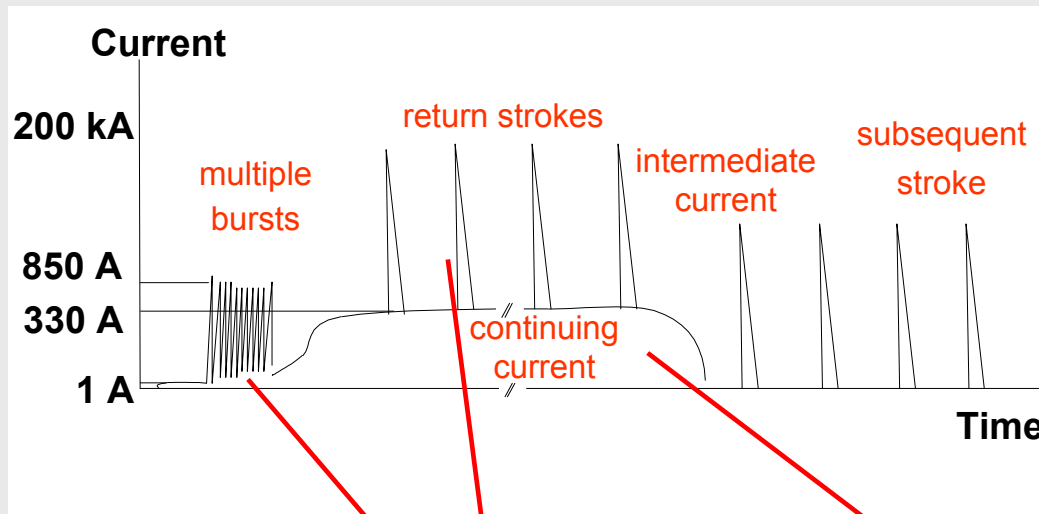
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The knowledge about lightning strike was received from three major research programs studying lightning strike interaction with aircraft: NASA Storm Hazards program, USA/FAA Lightning Characterization program, ONERA/CEV Transall programme

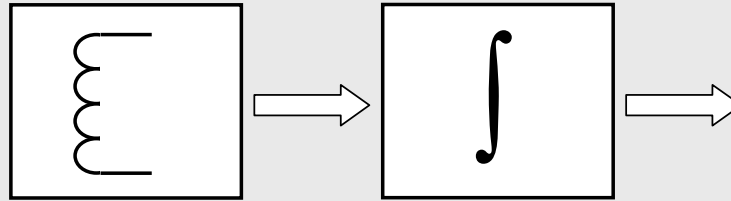


	I_{\min}	I_{\max}	F_{\min}	F_{\max}
Continuing current	± 40 A	± 900 A	1 Hz	100 Hz
Stroke	± 1 kA	± 200 kA	10 kHz	20 MHz
Burst	± 100 A	± 10 kA	200 kHz	≥ 20 MHz

bursts and strokes
inductive sensors based on Faraday's law.

continuing current:
solid state sensors or
Inductive sensors

Sensor assembly



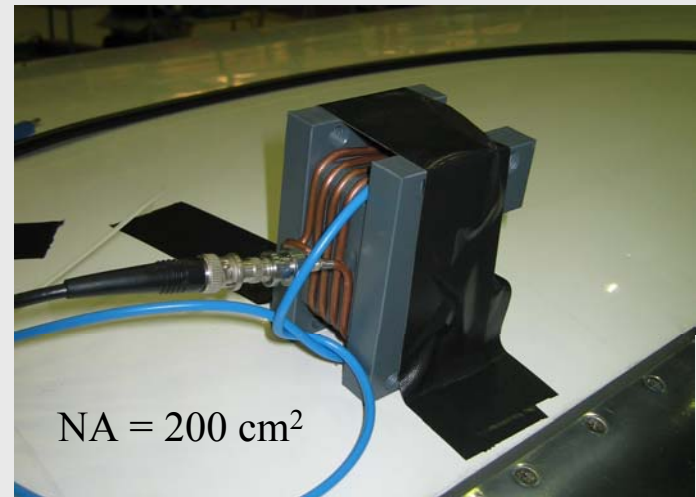
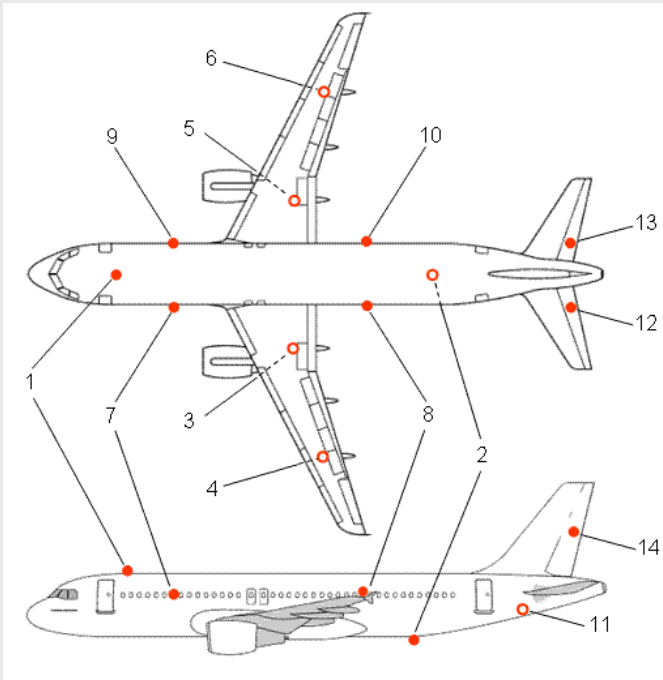
$$V_{\text{output}} = \mu_0 NAH / \tau$$

NA – number of turns time area

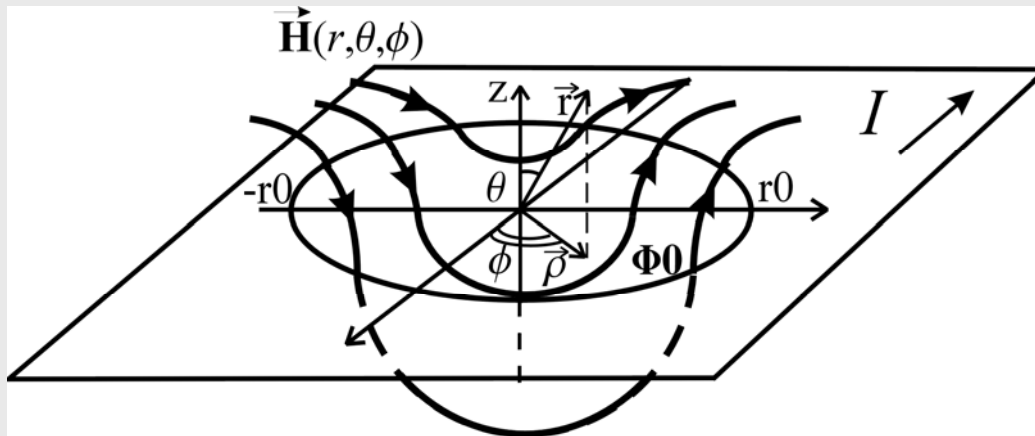
H – magnetic field

τ - time constant of integrator

Sensors possible locations



H. Kaden, *Wirbelströme und Schirmung in der Nachrichtentechnik*, Berlin: Springer, 1959, 2nd ed.

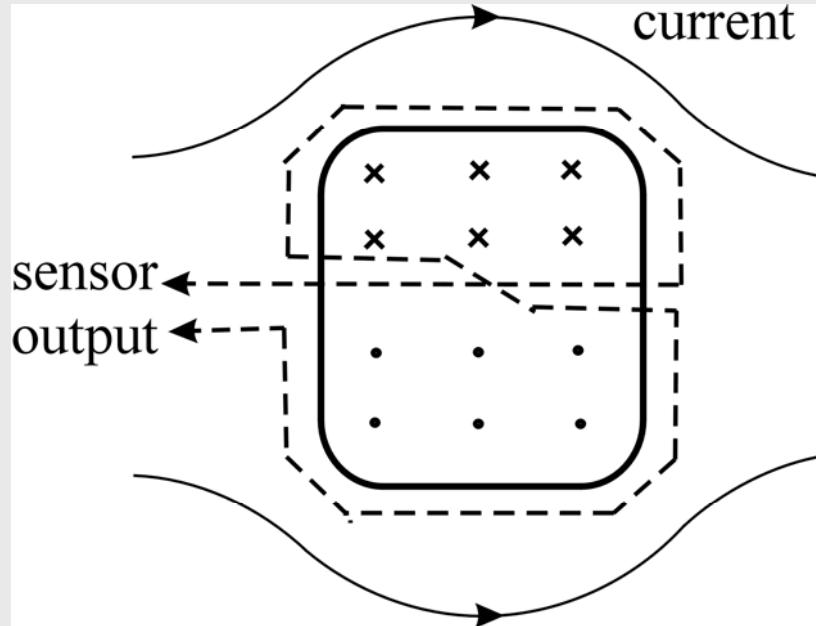


$$H_0 = \frac{I}{2\pi R}$$

$$\text{for } r_0 \leq r \quad X = H_0 r \sin \varphi \left[\frac{1}{2} \sin \vartheta + \frac{2}{\pi} \sum_{m=2,4,6\dots}^{\infty} \frac{(-1)^{\frac{m}{2}}}{m^2 - 1} \left(\frac{r}{r_0} \right)^{m-1} P_m^1(\cos \vartheta) \right]$$

$$\text{for } 0 \leq r \leq r_0 \quad X = -\frac{2}{\pi} H_0 r_0 \sin \varphi \sum_{n=1,3,5\dots}^{\infty} \frac{(-1)^{\frac{n-1}{2}}}{n(n+2)} \left(\frac{r_0}{r} \right)^{n+1} P_n^1(\cos \vartheta)$$

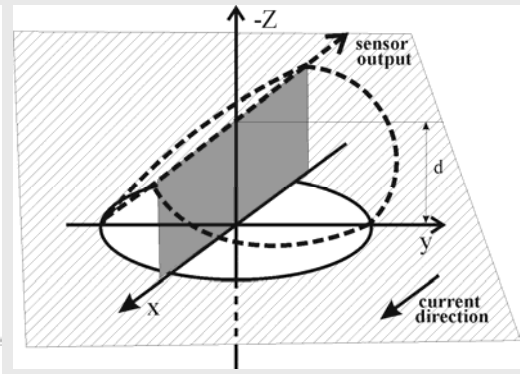
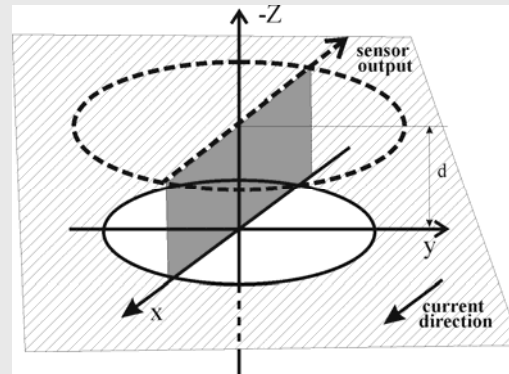
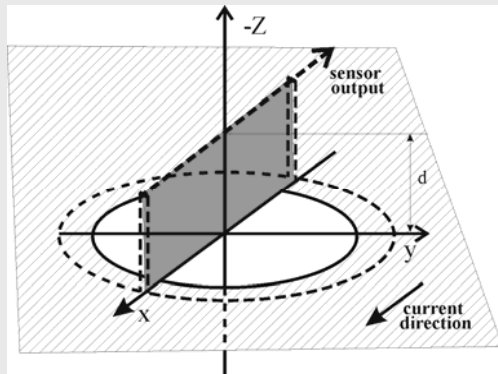
Window Sensor



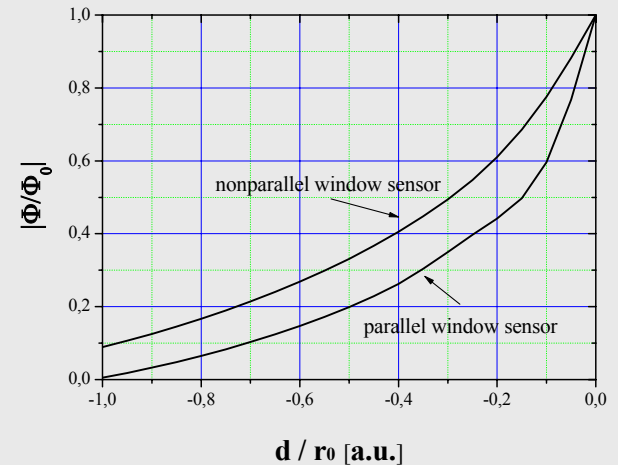
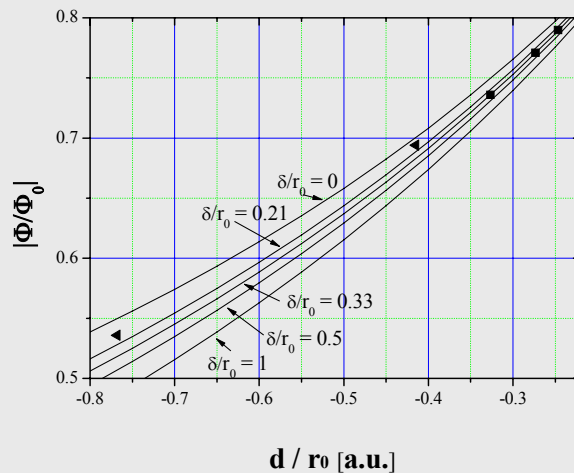
$$\Phi_0 = 2\mu_0 H_0 r_0^2$$

$$\Phi_s = \mu_0 \iint_S r^2 \sin \vartheta \frac{\partial X}{\partial r} d\vartheta d\varphi + \sin \vartheta \frac{\partial X}{\partial \vartheta} dr d\varphi + \frac{1}{\sin \vartheta} \frac{\partial X}{\partial \varphi} dr d\vartheta$$

Possible sensor positions according to the window



$$\frac{\Phi_d(d)}{\Phi_0} = 1 - \frac{\Phi_c(d)}{\Phi_{01}}$$



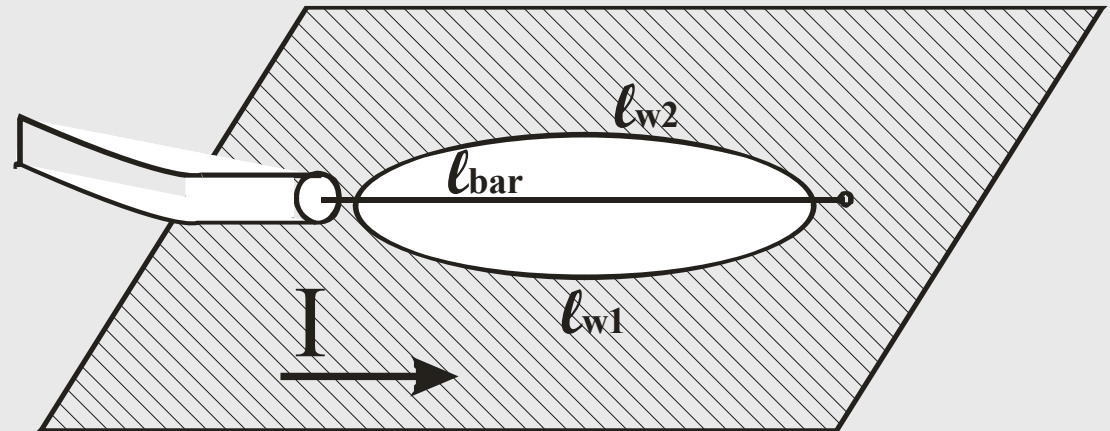
Single Wire Window Sensor

$$\int_{lw1} \vec{E} d\vec{l} + \int_{bar} \vec{E} d\vec{l} = -\frac{d\Phi_{01}}{dt}$$

$$\int_{lw2} \vec{E} d\vec{l} + \int_{bar} \vec{E} d\vec{l} = -\frac{d\Phi_{02}}{dt}$$

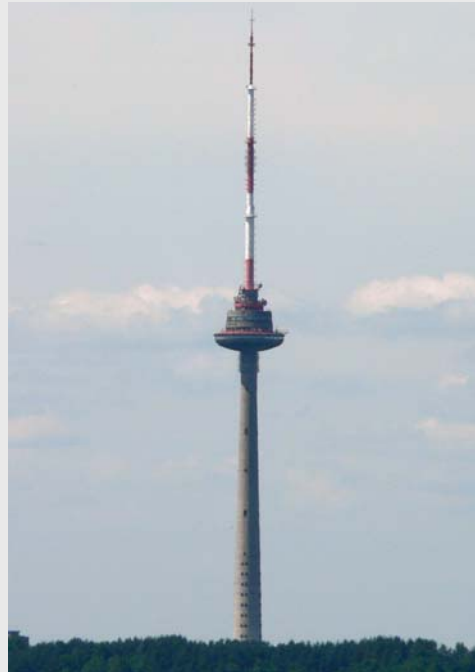
$$\int_{lw1} \vec{E} d\vec{l} + \int_{lw2} \vec{E} d\vec{l} = 0$$

$$\int_{bar} \vec{E} d\vec{l} = -\frac{1}{2} \frac{d\Phi_0}{dt}$$

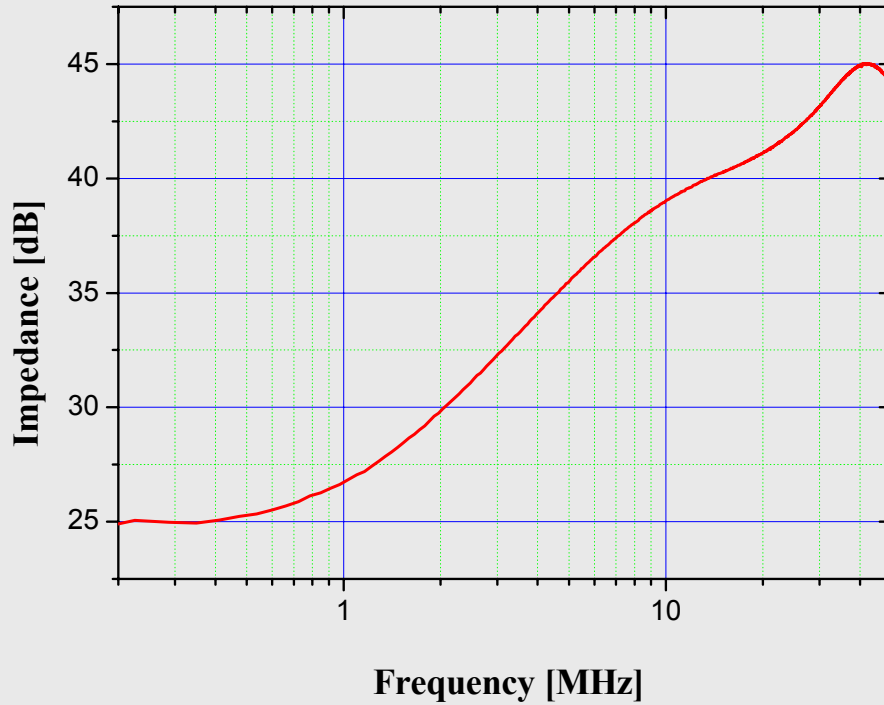


$$\Phi_0^s = \mu_0 H_0 r_0^2$$

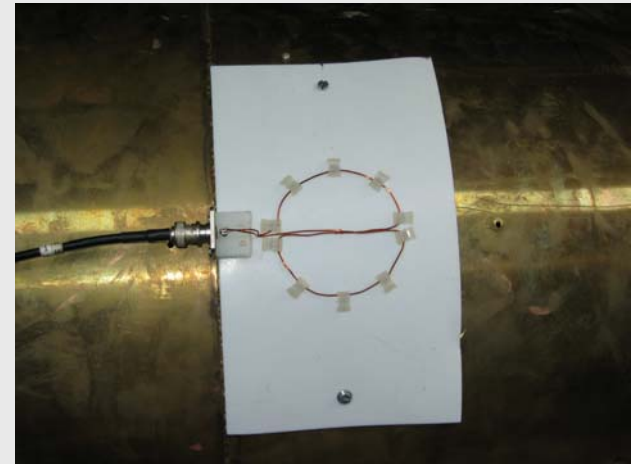
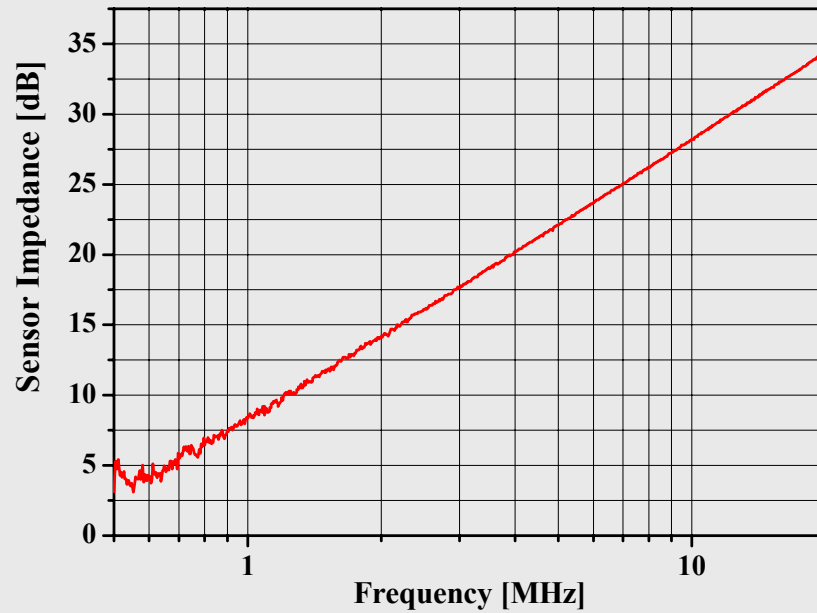
Possible utilizations



Window sensor impedance measured on metal plate



Window Sensor Impedance measured on metal tube



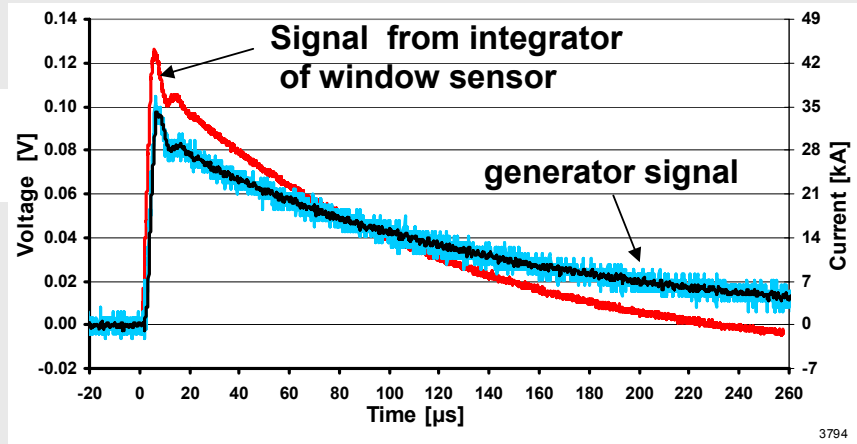
Picture of the window sensor mounted on the window of Nimrod aircraft
(photo courtesy BAE Systems)



Position of instrumented window



The input current to the aircraft and the output from the probe



Conclusion

For the fast stroke currents the inductive sensors are the best option. Special internal window sensor as a replacement of external coils sensors on fuselage has been proposed. Two types of the window sensor have been considered: loop and single wire probes. The second one has higher maximum frequency range. The loop window sensor is intended to be used when the probe and measuring object cannot be connected together. The sensitivity of the window sensor depends on the position. The maximum sensitivity is achieved when the sensor is placed on the window tightly. The window sensor possesses better frequency characteristic than the Rogowsky coil and can be a good replacement of it.