Direct Measurement of Lightning Current on Structures Using Fiber-Optic Sensor

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Abstract**—** A versatile optical fiber electric current sensor was developed to measure large current such as in direct lightning. It is highly suitable for challenging installation situations such as on aircraft. Based on Faraday Rotation Effect, it has many advantages over traditional sensors. This paper reports comparisons to a reference sensor measuring triggered lightning. Aircraft installation and flight demonstrations are discussed.

Keywords- lightning; current; Faraday; fiber-optic; sensor;

I. INTRODUCTION

A fiber-optic current sensor was developed to directly-measure lightning current, while meeting stringent aircraft installation requirements. It has many unique capabilities not possible with traditional current sensors. It does not suffer from hysteresis or magnetic saturation. It has large bandwidth, can measure DC component, and can capture the entire lightning waveform including continuing current. Installation is non-intrusive, simply by wrapping the sensing fiber around the current-carrying structure of interest. Being lightweight, flexible, structure-conforming and non-conductive make sensor installation simple and safe. Small sensor footprint minimizes aerodynamic drag or space concerns. These advantages could also benefit other lightning measurements such as on towers, windmills, power lines, etc. Electric current measurements other than lightning are also possible.

II. CONCEPT AND RESULTS

Faraday Rotation Effect causes light polarization in a sensing fiber to rotate when the fiber aligns with a magnetic field. The magnetic field strength can be determined from the light polarization change. By forming closed fiber loops and applying Ampere's law, measuring the total light rotation yields the total current enclosed. Implementation of a broadband, dual-detector, reflective polarimetric scheme (Fig. 1) allows measurement with an approximately 60 dB dynamic range [1-3].

Three similar systems were built with different laser wavelengths for different sensitivities. The 1310nm-based system, with range 300 A - 300 kA, was used in measuring current on simulated aircraft fuselage and other structures in laboratory settings. The effects of large current were simulated using multiple fiber loops and wire turns. Measurements of up to 200 kA lightning waveforms using only one fiber loop were demonstrated at a commercial test facility [2].

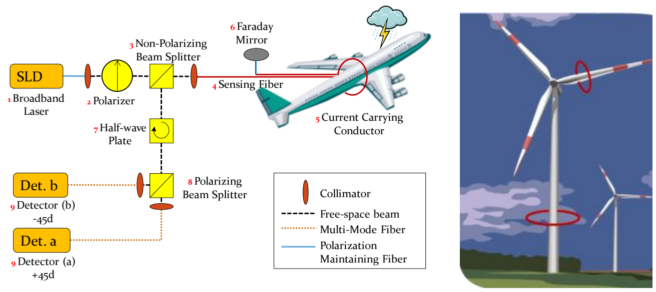

Figure 1: Measurement scheme and possible applications

The 850nm (range 140 A – 140 kA) and 1550nm systems (400 A – 400 kA) measured triggered lightning over two summers at the International Center for Lightning Research and Testing (ICLRT), Camp Blanding, Florida. The setups achieved excellent result comparisons against a reference shunt resistor. Examples are in show in Fig. 2.

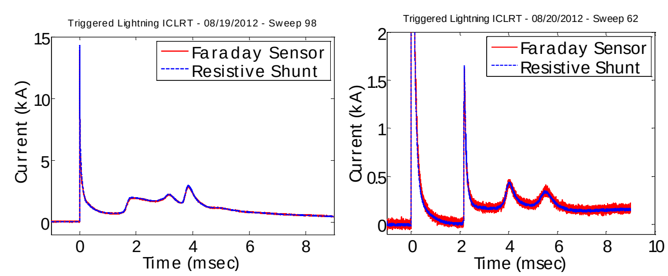

Figure 2: Rocket-triggered lightning measurement.

To illustrate the installation advantages, the 1310 nm system was flown on a Dassault Falcon 200 aircraft near thunderstorms on three separate occasions. The installation was simple without requiring aircraft modifications. The sensing fiber was wrapped around the outside of the fuselage, with its ends routed to a data recorder inside the cabin via an unused antenna hole. The entire system functioned normally throughout the flights.

REFERENCES

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