Space weather effects on communications

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In the last century and a half, since the invention and deployment of the first electrical communication system – the electrical telegraph – the variety of communications technologies that can be affected by natural processes occurring on the Sun and in the space environment around Earth have vastly increased. This chapter presents some of the history of the subject of space weather as it affects communications systems, beginning with the earliest electric telegraph systems and continuing to today’s wireless communications using satellites and land links. An overview is presented of the present-day communications technologies that can be affected by solar–terrestrial phenomena such as solar and galactic charged particles, solar-produced plasmas, and geomagnetic disturbances in the Earth’s magnetosphere and ionosphere.

9.1 INTRODUCTION

The discovery of magnetically confined charged particles (electrons and ions) around Earth by Van Allen (Van Allen et al., 1958) and by Vernov and Chudakov (1960) demonstrated that the space environment around Earth, above the sensible atmosphere, was not benign. Measurements by spacecraft in the five decades since Van Allen’s work has demonstrated that Earth’s near-space environment – inside the magnetosphere – is filled with particle radiation of sufficient intensity and energy to cause significant problems for satellite materials and electronics that might be placed into it.

Because of the trapped radiation (augmented by trapped electrons from the high-altitude Starfish nuclear explosion on 8 July 1962), the world’s first commercial telecommunications satellite, the low-orbit Telstar 1 (launched on 10 July 1962) (Bell System Technical Journal, 1963), suffered anomalies in one of its two command lines within a couple of months of its launch, and within five months both command lines
had failed. While clever engineering by Bell Laboratories personnel resurrected the satellite for more than a month in early 1963, by the end of February of that year Telstar had fallen silent for good – a victim of the solar–terrestrial radiation environment (Reid, 1963).

It was immediately clear from Van Allen’s discovery and then from the Telstar experience that the Earth-orbiting telecommunications satellites that had been proposed by Arthur C. Clark (1945) and by John Pierce (1954) prior to the space age would now have to be designed to withstand the Earth’s radiation environment. The semiconductor electronic parts (which were the obvious choice for even the earliest spacecraft and instrument designs) would have to be carefully evaluated and qualified for flight. Furthermore, the space radiation environment would have to be carefully mapped, and time dependencies of the environment would need to be understood if adequate designs were to be implemented to ensure the success of the missions.

9.2 EARLY EFFECTS ON WIRE-LINE TELEGRAPH COMMUNICATIONS

The effects of the solar–terrestrial environment on communications technologies began long before the space age. In 1847, during the eighth solar cycle, telegraph systems that were just beginning to be deployed were found to frequently exhibit ‘anomalous currents’ flowing in their wires. W. H. Barlow – a telegraph engineer with the Midland Railway in England – appears to be the first to have recognized these currents. Since they were disturbing the operations of the railway’s communications system, Barlow (1849) undertook a systematic study of the currents. Making use of a spare wire that connected Derby and Birmingham, Barlow recorded, during a two-week interval (with the exception of the weekend) in May 1847, the deflections in the galvanometer at the Derby station that he installed specifically for his experiment. These data (taken from a Table in his paper) are plotted in Figure 9.1. The galvanometer deflections obviously varied from hour to hour and from day to day by a cause (or causes) unknown to him and his fellow engineers.

The hourly means of Barlow’s data for the Derby to Birmingham link, as well as for measurements on a dedicated wire from Derby to Rugby, are plotted in Figure 9.2. A very distinct diurnal variation is apparent in the galvanometer readings: the galvanometers exhibited large right-handed swings during local daytime and left-handed swings during local night-time. The systematic daily change evident in Figure 9.2, while not explicitly recognized by Barlow in his paper, is probably the first measurement of the diurnal component of geomagnetically-induced Earth currents (which, of whatever time scale, were often referred to in subsequent literature in the nineteenth and early twentieth centuries as ‘telluric currents’). Such diurnal variations in the telluric currents have been recognized for many decades to be produced by solar-induced effects on the Earth’s dayside ionosphere (Chapman and Bartels, 1940).