

# Ionospheric Disturbances and Communication Signal Anomalies Due to Eruption of Solar Flare Activity

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## Abstract

*Solar flares tend to disrupt the radio communication systems and modulate active radio wave frequencies, particularly the ones which have utility in High Frequency (HF) radio signals and transceiver signals because they are the ones who find utility in radio communications systems. Solar flares generate electromagnetic waves which interact with the earth's atmospheric medium and travel through the ionospheric region. These electromagnetic waves modulate radio frequency communication signals. This modulation of waves or superposition of waves may be reflected, refracted, or diffracted due to interactions with several multi frequency electromagnetic waves. It is widely believed hypothesis that the propagation of radio waves in the ionosphere region is significantly influenced by the Sun's erratic behavior. Therefore, it has even a large impact on several high frequency (HF) radio communication waves that propagate for communication purposes like radio broadcasting waves and amateur radio communications, two-way radio communication, maritime mobile radio communication, general mobile radio employing the HF bands and point-to-point radio communication system.*

**Keywords:** Sudden ionospheric disturbances, signal modulation, auroras, railway communication

## INTRODUCTION

Solar flares discharge energetic particles which enter space and directly impact the earth's ionospheric region which is mainly navigated by radio communication signals. Solar electromagnetic radiations are mainly responsible for Solar-terrestrial activities, and massive eruptions of electromagnetic radiation from the Sun are known as solar flares. A solar flare emits energy that is more than a million times more powerful than the energy released by an Earth's volcanic explosion. Enormous explosions take place on the Sun's surface and enormous amount of energy is released. Large amounts of solid material are also ejected from the bigger solar flares, primarily in the form of protons. When these materials eject out from the Sun's surface in the form of gigantic arch, they reach temperature around millions of degrees and spread all over the space. Solar flares typically occur close to sunspots and frequently around sunspot boundaries where opposite magnetic forces have been present. Sometimes, it is observed that the magnetic fields initiate solar flares, and the magnetic lines of force may cross and rejoin so that it produces extremely powerful explosive energy into the space.

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These disturbances reach the Earth in the form of Solar flares and disrupt the earth communication system. Researchers have examined that solar flares can be viewed in white light only, but their intense X-rays frequencies and ultraviolet emissions can make them more noticeable. It is important to understand how solar flares affect the ionosphere to reduce disruptions and maintain reliable communication systems. This study looks at how solar flares cause changes in the ionosphere, how these changes impact communication signals, and

ways to predict and manage such disruptions. By tackling these issues, we can make communication networks more reliable during space weather events [1–7].

### Sudden Ionospheric Disturbance (SID) and Communication Signal

Sudden Ionospheric Disturbance (SID) refers to the sudden changes in ionospheric conditions due to erratic solar activity and is the most alarming and exceptional among all the ionospheric anomalies. These disruptions might happen suddenly and last anywhere between a few minutes and many hours. When SID takes place, the high frequency (HF) radio wave long-distance propagation is badly affected and is nearly completely "blacked out". Radio amateurs receiving off regular frequencies are also affected which in turn tends to assume that their transmitters are no longer in a functional mode because of this immediate effect. The solar flare tends to trigger an immediate and anomalous rise in the ionization density of the D layer due to an abnormally powerful burst of ultraviolet radiation that is not absorbed by the F2, F1, or E layers [8]. This leads to the communication signal frequencies beyond 1 or 2 MHz to get completely absorbed by the D layer. Strong solar flares might also trigger a significant geomagnetic storm, which tends to harm the communication signals as well as mobile devices, online services, GPS, satellites, power grids, and other electronic gadgets. Its impact can be seen on everything including Internet access and phone conversations [9–17]. These solar storms do result in the production of auroras in the northern and southern hemisphere and may provide a beautiful and breathtaking also known as northern lights sky display as shown in Figure 1 [18–22].



**Figure 1.** Northern and southern hemisphere solar flare associated auroras. (a) Northern hemisphere solar flare associated auroras, (b) Southern hemisphere solar flare associated auroras. Image courtesy of [www.pbs.org/newshour/science](http://www.pbs.org/newshour/science).

## LITERATURE REVIEW

It summarizes the state of knowledge regarding auroral radio absorption till 1968 and was written by Hargreaves [23]. If we wish to learn more about particulars of the subject, it refers to significant studies and highlights the most significant findings. To put it simply, it is a summary of the topic that points readers to more in-depth sources for further reading.

In their work, Hlubek *et al.* examine the frequency of scintillations, or signal disruptions, across the various global navigation satellite systems (GNSS) and their signal frequencies [24]. Galileo, GLONASS, and GPS systems are their main focus. The German Aerospace Center's (DLR) high-frequency GNSS station in Bahir Dar, Ethiopia, provides the data used in this investigation. This station measures the intensity of these signal disturbances by gathering data at a rate of 50 samples per second. The performance of these various systems and frequencies is compared in the article using the data that was gathered.

The formation of gravity waves at high latitudes and their migration towards lower latitudes have been the subject of research in the last decade. The Worldwide Atmospheric Gravity-wave Study (WAGS) and other worldwide models and observation initiatives have been used in these investigations. This review's first section provides an explanation of the research's conclusions [25].

Using a GPS monitor that tracks ionospheric disturbances (GISTM) and a camera that records the entire sky (ASC), Hosokawa *et al.* investigated ionospheric scintillation during an auroral substorm [26]. When a little substorm hit northern Scandinavia on November 19, 2009, they gathered data in Tromsø, Norway. In the study, the findings from these observations are discussed.

In this work, Hunsucker evaluates the literature on traveling ionospheric disturbances (TIDs) and atmospheric gravity waves (AGWs) at high latitudes [27]. It focuses on recent radar and other tool experiments. The article clarifies three key points: (1) how auroras produce AGWs that are connected to TIDs observed at lower latitudes, (2) the primary causes of AGWs, such as particle motions and heating, and (3) how the auroral ionosphere detects TIDs.

John *et al.* investigated the effect of ionospheric anomalies on GPS placement, specifically in the polar and auroral areas [28]. By altering the intensity and phase of radio signals from Global Navigation Satellite Systems (GNSS), these anomalies might result in location mistakes. Under peaceful to moderately disturbed magnetic circumstances, the study was carried out across three days in March 2018. The researchers analyzed the effects by combining measurements from EISCAT UHF/ESR incoherent scatter radars with GPS data. The two positioning techniques they looked at were precise static (PS) and broadcast kinematic (BK). The findings demonstrated that residual errors caused by ionospheric anomalies on the GPS signals contributed to an increase in positioning error, its unpredictability, and the incidence of data gaps.

Jonah *et al.* found that wave patterns caused by an explosion reached the ionosphere about 10 min after the event, suggesting acoustic gravity waves were involved [29]. These waves moved southeast at about 750 m/s and caused a change in electron content of 0.06 TECU. Their analysis also showed that the waves had a main repeating cycle of 1.5 to 2.5 min, corresponding to a frequency of 6.78 to 11 mHz in the ionosphere.

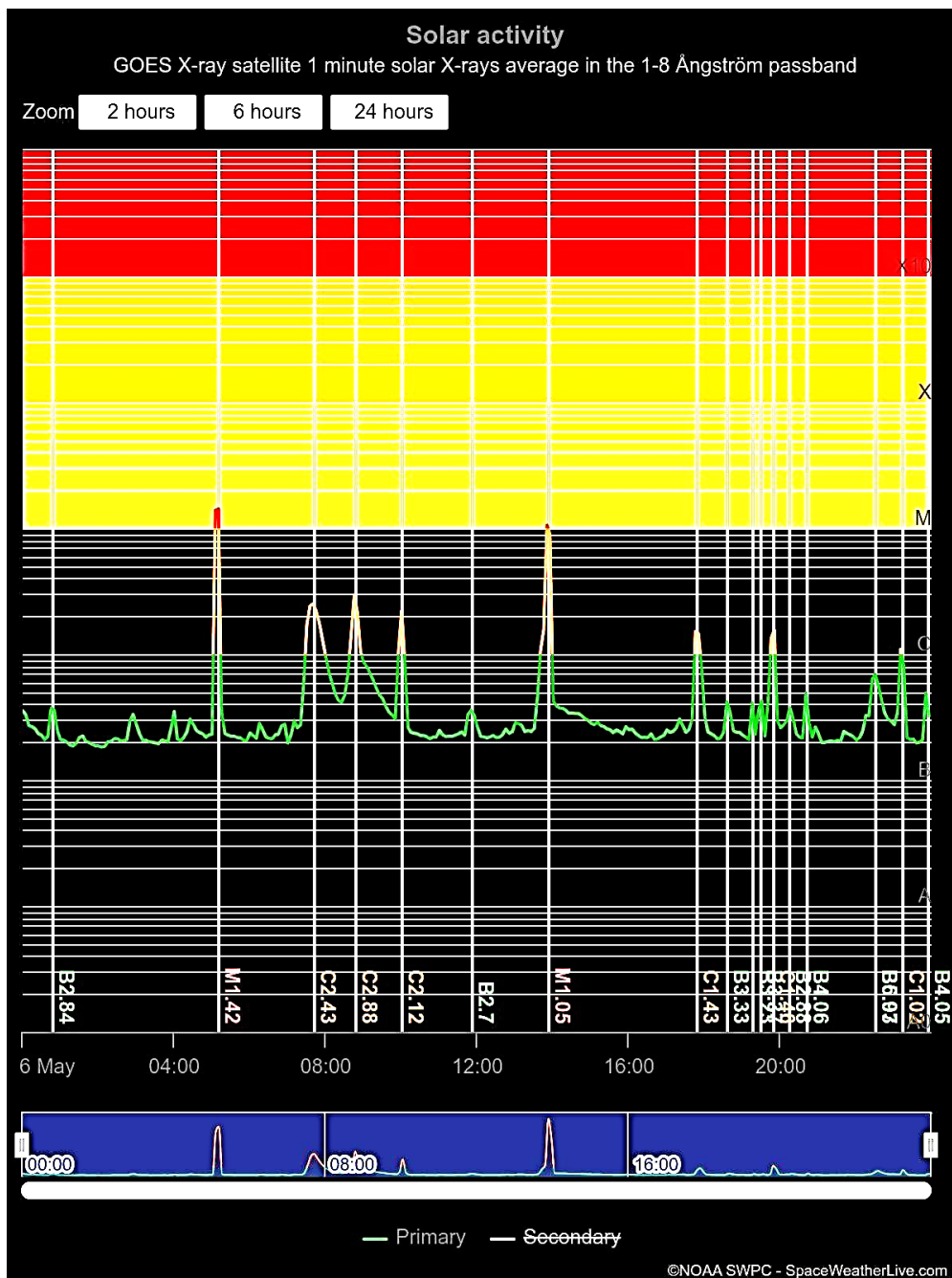
## MATERIALS AND METHODS

In the current study, type III solar flares have been chosen, which occurred on May 6, 2019, that follows a C2.88-class flare observed in the active region NOAA, GOES X-ray data. Northern Ireland Railways NIR Signal Posts—data.gov.uk observed modifications to the high frequency railway communication signal. A Northern Ireland Railways Platform is the facility which enables individuals to board or get off to railways at any platform or halt, as well as to load or unload cargo. The structures

that support NIR signals are visual display devices that provide instructions of alarms on a driver's permission for driving on a railway network known as railway signals. On May 6, 2019, the modified high frequency railway communication signal was observed during the proposed time. It has been triggered by solar flares, which accelerate electrons to a maximum flux density of 150–250 sfu in frequency interval which is noticed between 65 and 70 MHz, or up to  $2300 \text{ cm.s}^{-1}$ , or roughly 35% of the light's speed.

**RESULTS**

The results shown in Figure 2 indicate that the solar flare C 2.88 in the active region, observed using GOES X-ray data, peaks around the morning and daytime. This is followed by a significant release of energy, coinciding with the emission of other flares observed throughout the day.

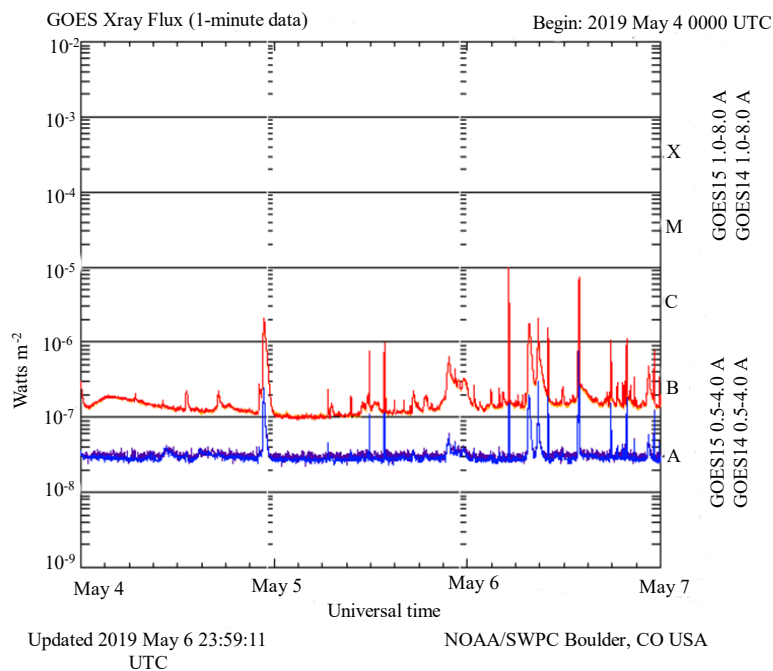


**Figure 2.** Solar flares occurred on Monday, 6 May 2019.

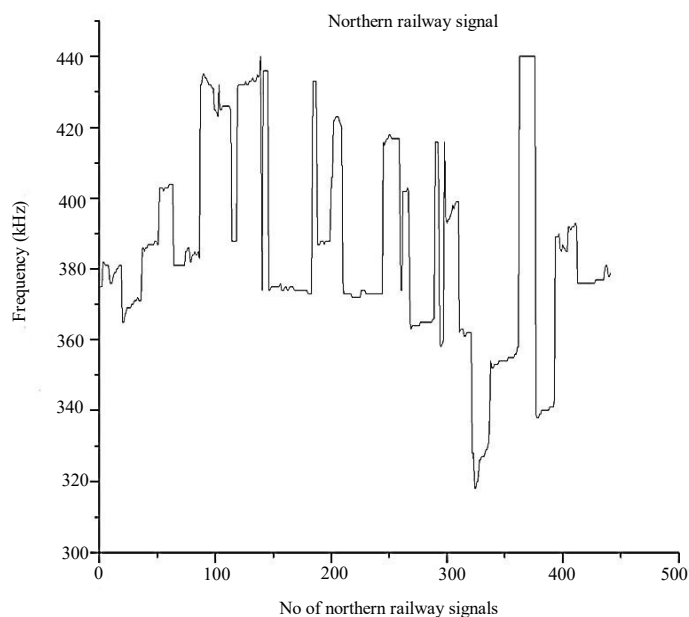
Various parameters associated with these events, which include the size, motion of radiation source and location are presented in Figure 3. A highly accelerated electron beam (accelerated between  $10^{-6}$  and  $10^{-5}$   $\text{Wm}^2$ , about 30% of the light's speed) triggered the solar flares which reached the maximum flux density of 0.5–0.4 A in the noticed frequency as depicted in Figure 3. The changing spectrum consisting of professed-periodic alterations was witnessed around 05:00:00 morning and 01:56:59 afternoon. UT also shows a solar flare with reduction in its frequency over time.

### DISCUSSION

The eruptions of solar flares on the 6th of May 2019, as shown in Figures 4 and 5 have a remarkable impact on the railway communication signal.

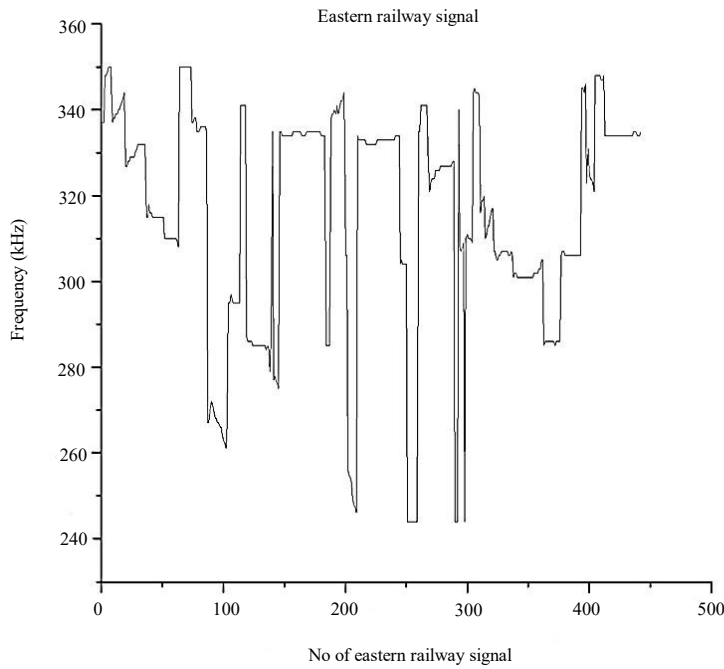


**Figure 3.** X-rays flux intensity on Monday, 6 May 2019.

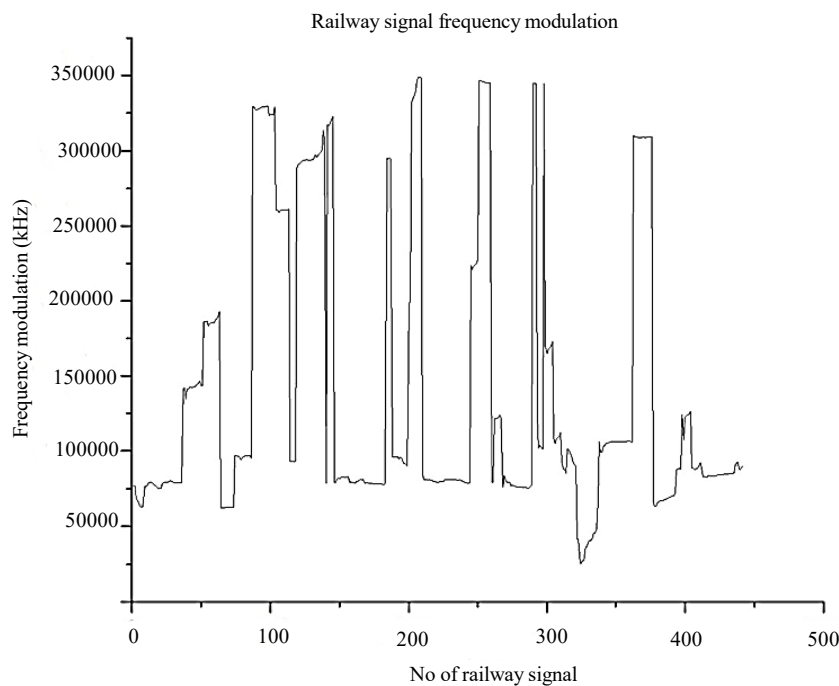


**Figure 4.** Northern railway communication signal strength in frequency on Monday, 6 May 2019.

The Northern Ireland Railway, Signal frequency fluctuation from 320–450 kHz is observed, as shown in the Figure 4, and the Eastern Ireland Railway Signal data shows 250–330 kHz frequency range, illustrated in Figure 5. The strength of high frequency communication signal is much impactful on the side of lower frequencies in the eastern Ireland railway frequency, owing to production of modulated waves. Further, in the Figure 6, modulated frequency ranges away from 350 kHz but synchronized around 50 kHz which provides a sufficient ground for the northern and southern hemisphere solar flares having non-thermic electrons to produce impactful emission due to progressing proportion of the crowdedness of the non-thermic electrons to plasma electrons.



**Figure 5.** Eastern railway communication signal strength in frequency on Monday, 6 May 2019.



**Figure 6.** Railway-signal waves frequency modulation.

## CONCLUSION

There are concerns that the solar flare, which is directly aimed at Earth, may damage high-frequency radio waves and possibly induce radio blackouts. The results of this research suggest that a strong solar wind was directed at Earth on May 6, 2019; a Monday, as mentioned in Figure 2. The solar flares at their fiercest can cause severe electrical problems such as satellite navigation failure, breakdown of energy systems, and blackouts. The Solar flares have been categorized as A, B, C, M, and X groups, where A being the weakest and X the strongest, then with a numerical value indicating their magnitude. The Figure 3, shows the X-rays Flux Intensity on Monday, 6 May 2019. Large aurora displays, satellite damage, radio blackouts, communication blockades, and even signal failure were all brought on by it. Solar flares can also malfunction railway signals. According to northern and eastern railway communication signal data shown in Figures 4 and 5. Space weather-induced electric currents can disrupt regular railway signaling system functioning, turning green lights red while no trains are in the area. Train whereabouts in railway networks are monitored by dividing the lines into discrete, consecutive sections called "blocks", which are typically 0.6–1.2 miles long. Every block has a signal attached to it that indicates whether a train is there at that moment. Relay systems that monitor solar wave modulations and control observation signals are shown in Figure 5. When a current has been identified in a block that is not occupied by a train, the signal lights become red; otherwise, they turn green. Solar flares can turn on red lights on railway tracks during their intended off-state by creating currents in the railway system.

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