Observations of Ionospheric Radio Propagations in the Arctic and the Mid-latitude Regions

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1. Introduction

Natural phenomena, such as solar flare and sporadic E layer, have some influences on radio propagation characteristics. Since radio waves are utilized for many broadcasting and communications systems today, it is important to observe the influences of the natural phenomena on radio propagations. And it is also useful to observe the radio propagations for a long term and in different propagation paths from the view points of understanding and investigating mechanisms of natural phenomena.

Until now, in our laboratory, to investigate clarify the relationship between natural phenomena and radio propagations, we observed terrestrial, tropospheric and ionospheric radio propagations in several frequency bands from LF band to UHF band at our radio observatories established all over Japan. And our 24-hour continuous observations lasting over 10 years indicated that the radio propagations were affected by many natural phenomena such as galactic noise, solar flare, sporadic E layer, thunder lightning and atmospheric ducting[1][2].

Especially MF band ionospheric radio propagations are sensitive to the solar activity because the ionosphere is upper atmosphere ionized by radiations, both electromagnetic and corpuscular, from the sun[3]. It is well known that the MF band radio waves are absorbed by ionospheric D layer in daytime and are greatly propagated over the horizon by reflecting at E layer in nighttime because of D layer disappearance[3]. It is effective to observe the MF radio propagations not only in Japan but also in other country, not in the mid-latitude region, to clarify more detail ionospheric phenomena.

The authors newly installed the radio observation sites in Kiruna, Sweden in addition to Noro and Misato, Japan to observe MF band ionospheric propagations. And we have continued the observations since their installations to investigate or compare the propagation features between the Arctic and the mid-latitude regions. Our observations in MF band were started from June in 2010 at Noro and Misato sites and started from September in 2011 at Kiruna site. The observational frequencies were selected around 1,000 kHz of AM radio broadcasting waves. There were non-line-of-sight paths between the broadcasting sites and observatories.

This paper describes the observation method and propagation paths, and shows observation results on received levels of MF band radio waves over 6 months period. After some discussions based on the observations, we conclude that the MF band ionospheric radio propagations in the Arctic were sensitively affected by the solar activities than propagations in the mid-latitude region.

2. Observations

2.1 Radio Propagation Environments

To observe MF band ionospheric propagations, we have utilized on-air AM radio broadcasting waves. Since it is necessary to identify the source of the radio propagations, we have selected the AM broadcasting stations with higher transmitting power over 50 kW. And we constructed radio observatories in Noro (NRO) and Misato (MST), Japan and in Kiruna (KRN), Sweden in order to compare the propagation characteristics between the mid-latitude region and the Arctic. Fig. 1 and Fig. 2 show the observation propagation paths in Japan and Europe, respectively. In Japan, we have selected two MF band AM broadcasting waves; The radio station of TBS Tokyo

Hoso (Freq.: 954 kHz, Power: 100 kW) is located in Toda (TOD), and the radio station of RF Radio Nippon (Freq.: 1,422 kHz, Power: 50 kW) is located in Yokohama (YKH) as shown in Fig. 1. The propagation distances between TOD and NRO, TOD and MST, YKH and NRO, YKH and MST are about 659 km, 430 km, 650 km, and 412 km, respectively. Around Sweden, we have selected two MF band AM broadcasting waves; The station of Radio Eli (Freq.: 1,035 kHz, Power: 200 kW) is located in Estonia (EST), and the station of Radio Romania (Freq.: 1,179 kHz, Power: 200 kW) is located in Romania (ROM) as shown in Fig. 2. The propagation distances between EST and KRN, ROM and KRN are about 1,100 km and 2,380 km, respectively. There are non-line-of-sight paths in all propagation profiles.

2.2 Observational Systems

Fig. 3 illustrates the basic configuration of our observational systems. In the systems, the monopole antenna was installed on the rooftop of the building. And the wideband receivers were utilized to detect the MF band radio waves. The detected RSSI data were converted to digital data by the AD convertor. The PC was used for continuously logging data of the received levels with sampling interval of 2 seconds. The observational data were transferred to remote server in our university through the Internet. The observational time was adjusted by GPS clock. Table 1 shows the specifications of the observational systems. The RSSI (Received Signal Strength Indicator) data were calibrated to the received levels and the calibration error was within 1 dB. The observational limitation was -100 dBm in received levels.

3. Results and Discussions

This paper presents observational results obtained from September in 2011 at all observation sites. The observational results of the received levels of the MF band radio waves in NRO, MST and KRN are shown in Fig. 4, Fig. 5 and Fig. 6, respectively. In these figures of received levels, the vertical axes show month/day and the horizontal axes show local time in Fig. 4 and Fig. 5 and universal time in Fig. 6.

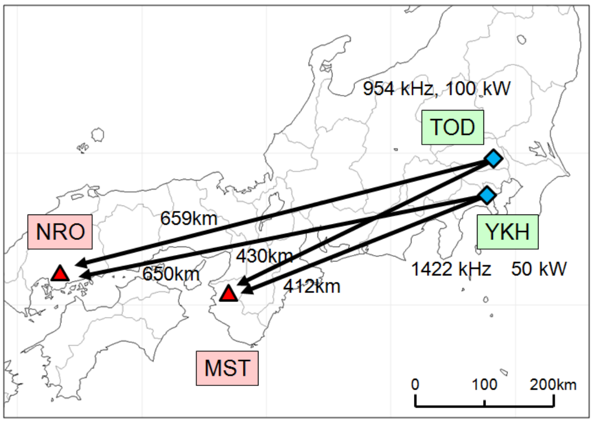

Fig.1 Observation propagation paths in Japan

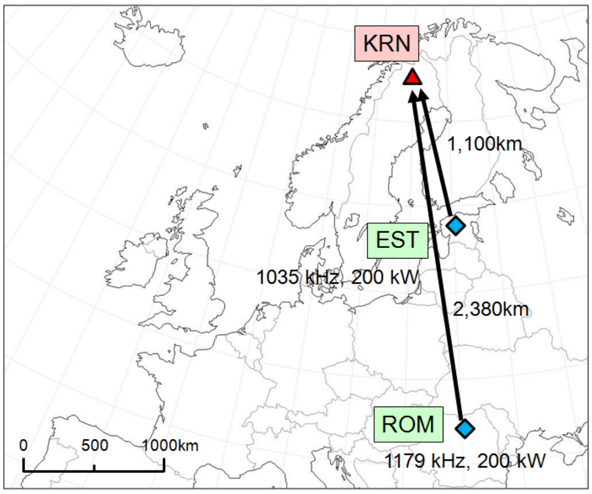

Fig.2 Observation propagation paths in Europe

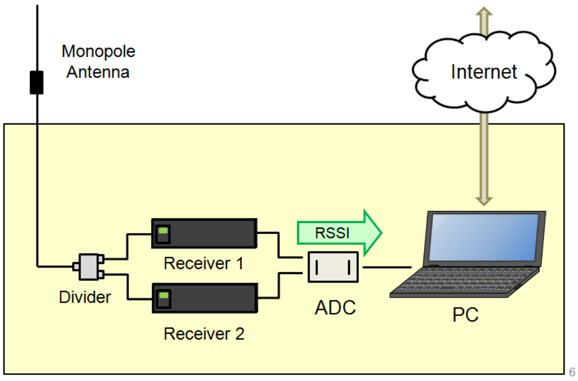

Fig.3 Observational System Configurations

Table 1 Observational System Specifications

Frequency band	MF band
Receiving antenna	Monopole
Receiving bandwidth	6 kHz
Measurement limitation	−110 dBm
A/D resolution	13 bit

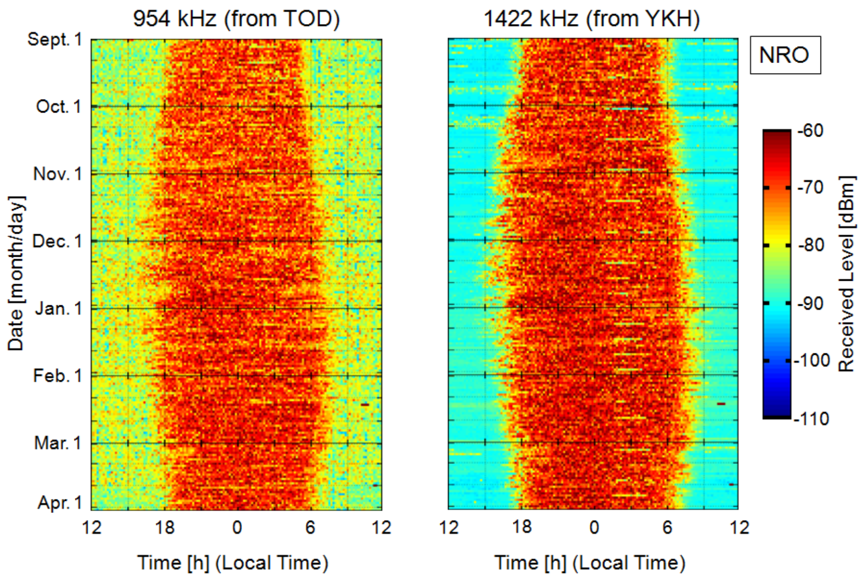

Fig. 4 Received Levels of Radio Waves from TOD and YKH to NRO in Japan

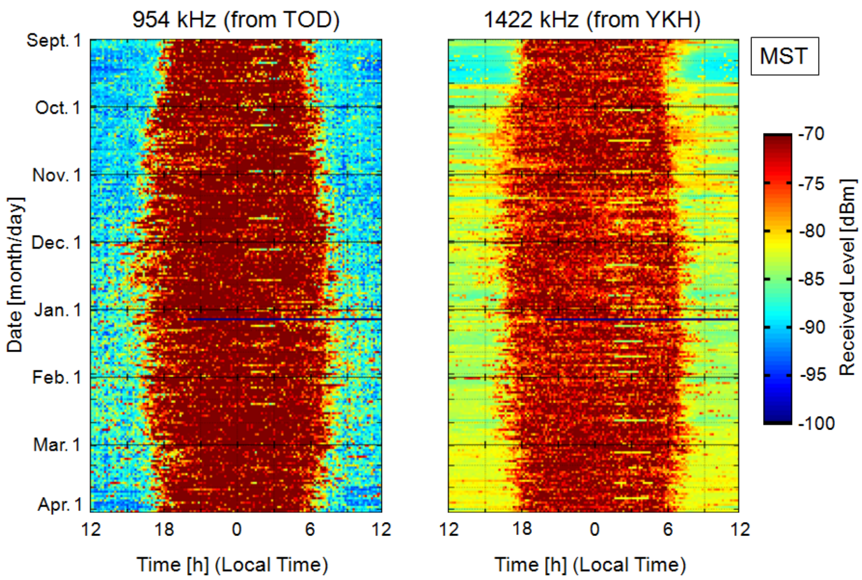

Fig. 5 Received Levels of Radio Waves from TOD and YKH to MST in Japan

From all figures, it is found that the received levels of the MF band radio waves in nighttime are 20 dB or 30 dB higher than those in daytime. And the time of the received levels' rising up and falling down was related to that of sunrise and sunset. These trends are the same even if the propagation distances are different from each other between NRO and MST observation environments, as shown in Fig. 4 and Fig. 5. And these trends are almost same between the Arctic and the mid-latitude regions as shown in Fig. 6. And it is also found that the higher the latitude of the propagation path, the longer the period between the rising and the falling times; The longest period was observed in the propagation from EST to KRN. We consider that the reason of these trends is that the MF band radio waves are absorbed by ionospheric D layer in daytime and are greatly propagated over the horizon by reflecting at E layer in nighttime because of D layer disappearance.

From Fig. 6, it is also found that there are unusual variations of received levels in only KRN observational results. For example, around Sept. 27 in 2011, Jan. 30 and March 10 in 2012, the received levels did not increase even in nighttime. Each unusual variation was observed a few days after a solar flare occurred; X1.4, X1.7 and X5.4 class solar flares occurred on Sept. 24 in 2011, Jan. 27 and March 7 in 2012, respectively[4]. It is conceivable as the reason of the variations that

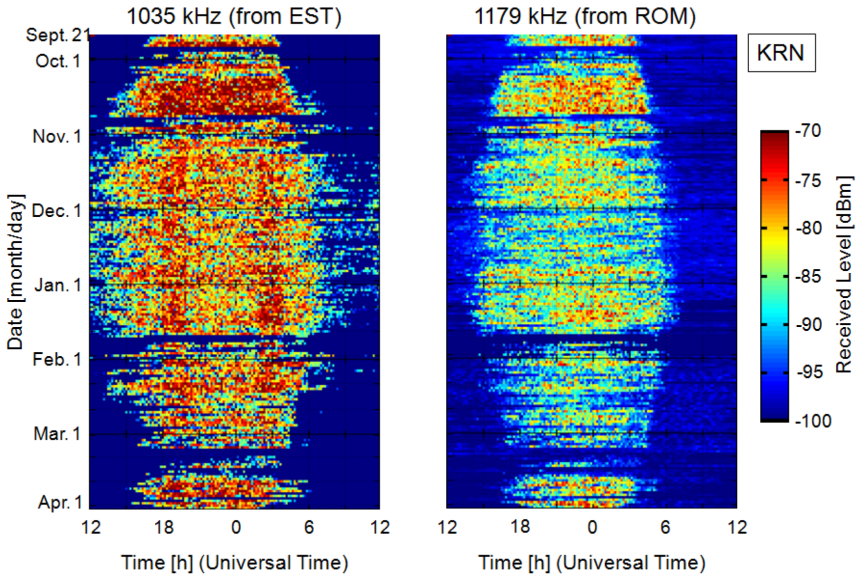

Fig. 6 Received Levels of Radio Waves from EST and ROM to KRN in Europe

massive plasma particles radiated from the solar flare are provided to the Arctic ionosphere and the electron density of D layer is not reduced, then the MF band radio waves are absorbed even in nighttime. At the same time, aurora borealis also were observed in Kiruna; the aurora phenomena are considered to be evidences of the massive plasma particles entering the Arctic ionosphere. The observational results suggest that, in the MF band, the ionospheric radio propagations in the Arctic are more sensitively affected by the solar flare than propagations in the mid-latitude region.

4. Conclusions

- The received levels of the MF band radio waves in night time are 20 dB or 30 dB higher than those in day time, both in the Arctic and the mid-latitude regions. And the time of rising and falling was related to that of sunrise and sunset.
- Only in the Arctic, there were unusual variations of the received levels without rising up, which were observed a few days after the solar flare occurred. At the same time of the unusual variations, aurora borealis also were observed.
- In the MF band, the ionospheric radio propagations in the Arctic were more sensitively affected by the solar flare than propagations in the mid-latitude region.

Acknowledgments

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