Climatology of Maximum Usable Frequency at High Latitudes

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Summary:

- Years of multi-frequency HF radio transmission data for a cross-auroral zone link and a polar cap link are used to investigate how the maximum usable frequency varies with time, and with geomagnetic activity.
- Both links show a clear reduction in MUF connected to concurrent geomagnetic activity, distinct from the expected diurnal variation.
- The MUF for the polar cap link is increased at times when patches are expected to appear in the polar cap.

Background:

- HF radio propagation is important for high latitude communications and surveillance due to the lack of alternative infrastructure.
- A key parameter for evaluating the capability of the ionosphere to propagate HF radio waves is the maximum usable frequency.
- Information on when the MUF can be expected to be reduced or elevated can help inform HF radio operators of when to expect problems.

Data:

- We use observations from two multi-frequency HF radio links that operated from 2012-1017 (see Table 1 for more details):
  - OTT-ALE, a cross-auroral link from Ottawa (45.4° N, 75.7° W) to Alert (82.5°N, 62.3°W),
  - QAN-ALE, a polar cap link from Qaanaaq (77.5° N, 69.2° W) to Alert.
- As a proxy for MUF, the maximum received frequency (MRF) was calculated for each hour interval by recording the highest frequency for which > 50% of transmitted signals were received.
- Figure 1 shows an example of how the MRF for OTT-ALE varied across few days with moderate geomagnetic activity.

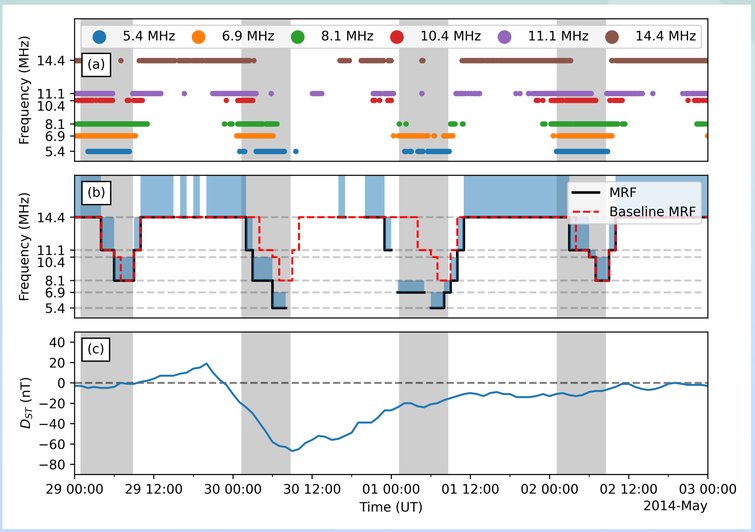

Figure 1: (a) Frequencies detected at Alert from Ottawa, (b) MRF in black, and baseline (quiet-time) MRF in red, and (c) D_{ST} index versus time.

MRF Climatology:

- Figure 2 shows the mean MRF vs time of day and date for (a) OTT-ALE transmissions and (b) QAN-ALE transmissions.
- OTT-ALE is dominated by diurnal variation, where the MRF peaks when the sun is highest in the sky.
- QAN-ALE shows a different pattern, where the MRF is highest in the UT evening near winter solstice and in the UT morning near the equinoxes.

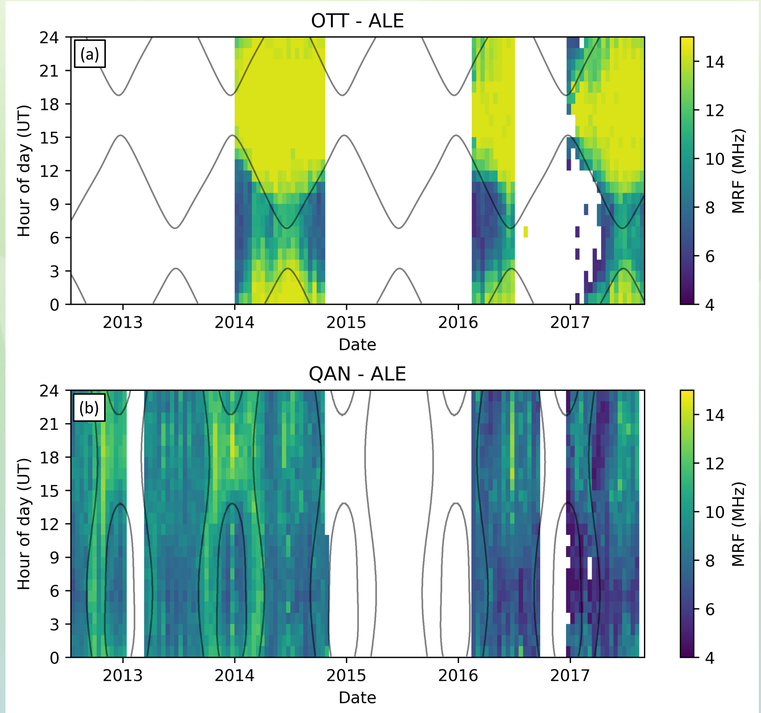

Figure 2: Mean biweekly MRF versus hour of the day (UT) and date for (a) OTT-ALE, and (b) QAN-ALE. Contours in (a) indicate sunrise and sunset times at the midpoint between OTT and ALE, contours in (b) enclose times when patches are likely to occur in the polar cap based on the David et al. (2019) patch occurrence model.

Storm Effects:

- Figure 3 shows the mean MRF for each hour of the day, binned by D_{ST} level, for both links. Lower D_{ST} values are clearly connected to lower MRF for both links.
- The observed plateau in daytime MRF for OTT – ALE is due to 14.4 MHz being the maximum frequency transmitted by OTT.

Link	Transmitted Frequencies (MHz)	Cadence (/hr)	Time Range
OTT-ALE	5.4, 6.9, 8.1, 10.4, 11.1, 14.4	4 – 24	Jan 2014 – Aug 2017
QAN-ALE	4.6, 7.0, 8.0, 10.4, 11.1, 18.4	4 – 30	Jul 2012 – Aug 2017

Table 1: Frequencies and cadences (per frequency) of transmission, and time ranges of operation for both HF radio links.

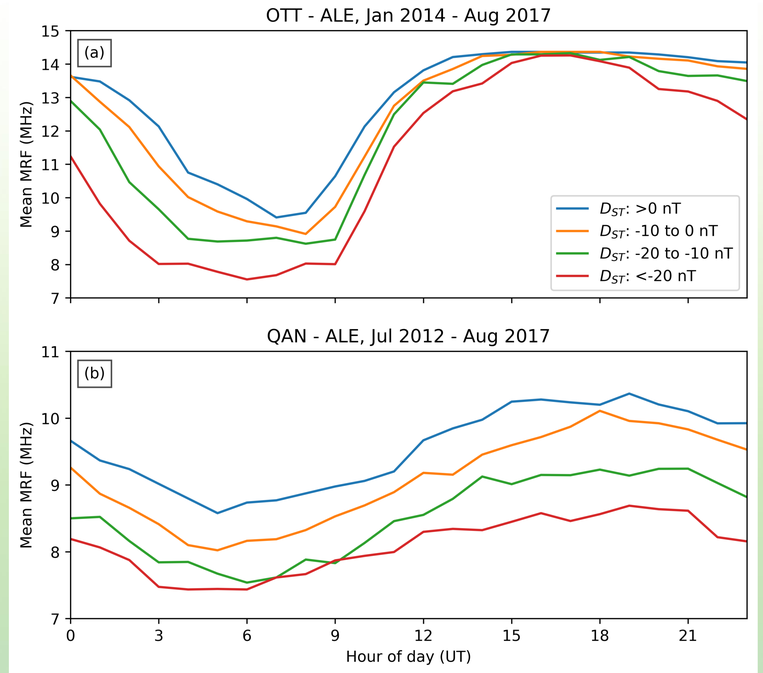

Figure 3: Mean MRF versus hour of the day, binned by concurrent D_{ST}, for (a) OTT-ALE transmissions, and (b) QAN-ALE transmissions.

Polar Cap Patch Effects:

- The pattern of high MRF seen in Figure 2b is consistent with a simple model of polar cap patch occurrence introduced by David et al. (2019).
- The David et al. (2019) model states that patches are likely to occur in the polar cap when:
  - The magnetic north pole is not sunlit, and
  - The polar cap convection turnaround point (70° magnetic latitude at 1200 MLT) was sunlit two hours ago.
- These times are bounded by the black contour lines in Figure 2b.
- Figure 4 shows the mean MRF versus SZA, binned by this patch occurrence model. The mean MRF is higher when patches are likely to occur in the polar cap.

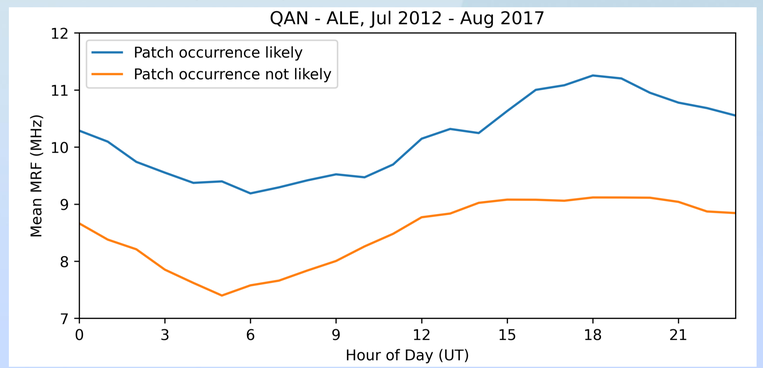

Figure 4: Mean MRF versus hour of day (UT), binned by the David et al. (2019) patch occurrence time model for QAN-ALE transmissions

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Bibliography:

David, M., Sojka, J. J., Schunk, R. W., & Coster, A. J. (2019). Hemispherical shifted symmetry in polar cap patch occurrence: A survey of GPS TEC maps from 2015–2018. Geophysical Research Letters, 46, 10726–10734. https://doi.org/10.1029/2019GL083952