A Snapshot of Propagation Characteristics Observed by TIGER

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ABSTRACT

TIGER was operated as a swept-frequency backscatter sounder for a two-day period in February 2000. The subsequent ionograms provide an overview of HF propagation conditions in the form of a frequency-range map of ionospheric scatter and standard HF propagation modes supported by the prevailing ionospheric conditions. Mode identification is aided by angle-of-arrival measurements as well as velocity and spectral width measurements. This paper presents some examples and discusses and presents some comparison with model calculations.

1. INTRODUCTION

TIGER began operations in November 1999. As part of our program to evaluate the performance of the radar, a series of swept-frequency backscatter ionograms were obtained on 19-20 February 2000. Beam 4 was used (see Figure 1), the radar swept over the range 8-20 MHz every 15 minutes and taking 6 minutes to complete a scan. This paper briefly discusses several examples of the data collected.

In interpreting the data, it is of value to review some of the most basic types of echo trace signatures that will be observed. i.e. when there is backscatter from the ground and, ionospheric backscatter emanating from a fixed true range. Figure 2 depicts ray paths that give rise to fist hop ground or sea scatter and ionospheric scatter at 0.5 and 1.5 hops.

Figure 3 is a simulation of a swept-frequency backscatter ionogram for a horizontally stratified ionosphere containing E, F1 and F2 layers. The simulation was carried out using the method described by Dyson et al. (1988) and it considers all propagation paths supported by the ionosphere but does not include ionospheric absorption. The main points to note are that:

- for the ionosphere considered, the leading edges of the E, F1 and F2 layers happen to form a fairly continuous leading edge;
- at each frequency the group range window is typically more than a 1000 km;
- by suitable choice of frequency, the single hop backscatter can extend well beyond 3000 km.

Of course if second hop ground scatter were included there would be another set of echo traces with twice the group range. If ionospheric scatter were widespread throughout the ionosphere, then replicas of the echo traces would also occur at appropriate ranges, such as 0.5, 1.5 or 2.5 times the range of the first hop ground scatter.

Figure 4 is an example of an oblique ionogram for transmission over a fixed path, where both transmitter and receiver are on the surface of the Earth. If ionospheric scatter is caused by irregularities at approximately a fixed range, such as would occur if the irregularity region has a sharp boundary, then the same of type of swept-frequency echo trace will be observed. Note that as the number of ionospheric hops is increased, the swept-frequency echo trace becomes more like the classic echo signature observed by a vertical incidence sounder.

2. OBSERVATIONS

Figure 5 shows a TIGER backscatter ionogram obtained when there were no ionospheric irregularities within the radar field of view causing scatter. At most frequencies there is strong first-hop sea scatter from a narrow range window defined by ionospheric conditions and the antenna system. The plots of echo velocity and spectral width show no significant velocity features so the echoes are all due to sea scatter. As expected for HF propagation, the region of sea scatter moves steadily out to longer ranges as the transmitting frequency is increased. Second hop sea scatter is also evident at the lower frequencies. No ionospheric scatter is evident over the entire range out to 3000 km is covered during the frequency sweep, there were clearly no ionospheric irregularities present in the region at this time. This is not surprising considering that the observation was made at about 1000 LT.

The propagation has been modelled using the International Reference Ionosphere (Bilitza, 1996) prediction for the ionosphere located 1500 km south of the radar and the results are shown in Figure 6. The comparison on the leading edge echoes clearly indicate a weaker E layer echo trace at slightly closer apparent range than the stronger F2 layer trace. When the antenna patterns and dynamic range of the system is considered the basic shape of the echo traces is reproduced quite well (Figure 7).

The elevation angle behaves as expected:

- the E layer echoes are at a higher elevation than the F2 echoes;
- within the F2 echo trace the elevation angle decreases with increasing range;
- at a fixed apparent range, the elevation increases with frequency.

While the elevation angle variations are as expected, the actual values are up to 5 degrees higher than the model predicts. This may be due to the fact that latitudinal gradients were ignored in the modelling, or it could be due to phase errors not yet accounted for in the interferometer. Further tests are under way to resolve this apparent discrepancy.

A second backscatter ionogram example, (Figure 8) shows a patch of ionospheric backscatter at 2.5 hops over the frequency range 8 - 10 MHz and at 1.5 hops over the frequency range 10 - 13 MHz. These echoes also have non-zero velocity, further confirming that they are ionospheric backscatter rather than sea scatter which has either zero or relatively low velocity. These echo signatures are similar to standard oblique ionogram echoes, (see Figure 4), indicating that the ionospheric scatter is coming from a well-defined scattering feature in the ionosphere, such as an equatorward wall of a region of irregularities. Note also the change in the echo trace shape between the 1.5 and 2.5 hop traces. Clearly on this occasion ionospheric convection could be studied using any frequency up to 13 MHz but the propagation mode would need to be identified to correctly map the location of the scatter region.

A third example is shown in Figure 9 in which only the spectral width is shown. It is evident that in this night-time case, ionospheric irregularities are widespread as the frequency-range signature of the ionospheric scatter at 1.5 hops is essentially identical to the signature of the one-hop sea scatter.

These illustrative observations demonstrate the capabilities of the TIGER system that is now operating continuously, conducting scientific campaigns on a monthly basis.

3. SUMMARY

The TIGER swept-frequency backscatter ionograms show that the system is operating very well, apart from some uncertainty in the angle-of-arrival measurement. The complete set of backscatter ionograms obtained over the 19-20 February 2000 period show a wide range of propagation features and it is planned to investigate these more fully. Some additional examples are given in the Appendix containing the complete set of Figures presented at Beechworth.

4. ACKNOWLEDGEMENTS

TIGER has been funded by contributions from the organisations represented by members of the Management Team, the Australian Research Council and the Antarctic Foundation. Members of the SuperDARN international community, particularly at British Antarctic Survey and University of

Leicester, have contributed significantly to TIGER's development through the provision of essential software, circuitry and much advice.

5. REFERENCES

Bilitza, D. International Reference Ionosphere, http://nssdc.gsfc.nasa.gov/space/model/ionos/iri.html, 1996.

Dyson, P. L. and J. A. Bennett. A model of the vertical distribution of the electron concentration in the ionosphere and its application to oblique propagation studies, *J. Atmos. Terr. Phys.*, 50, 251-262, 1988.

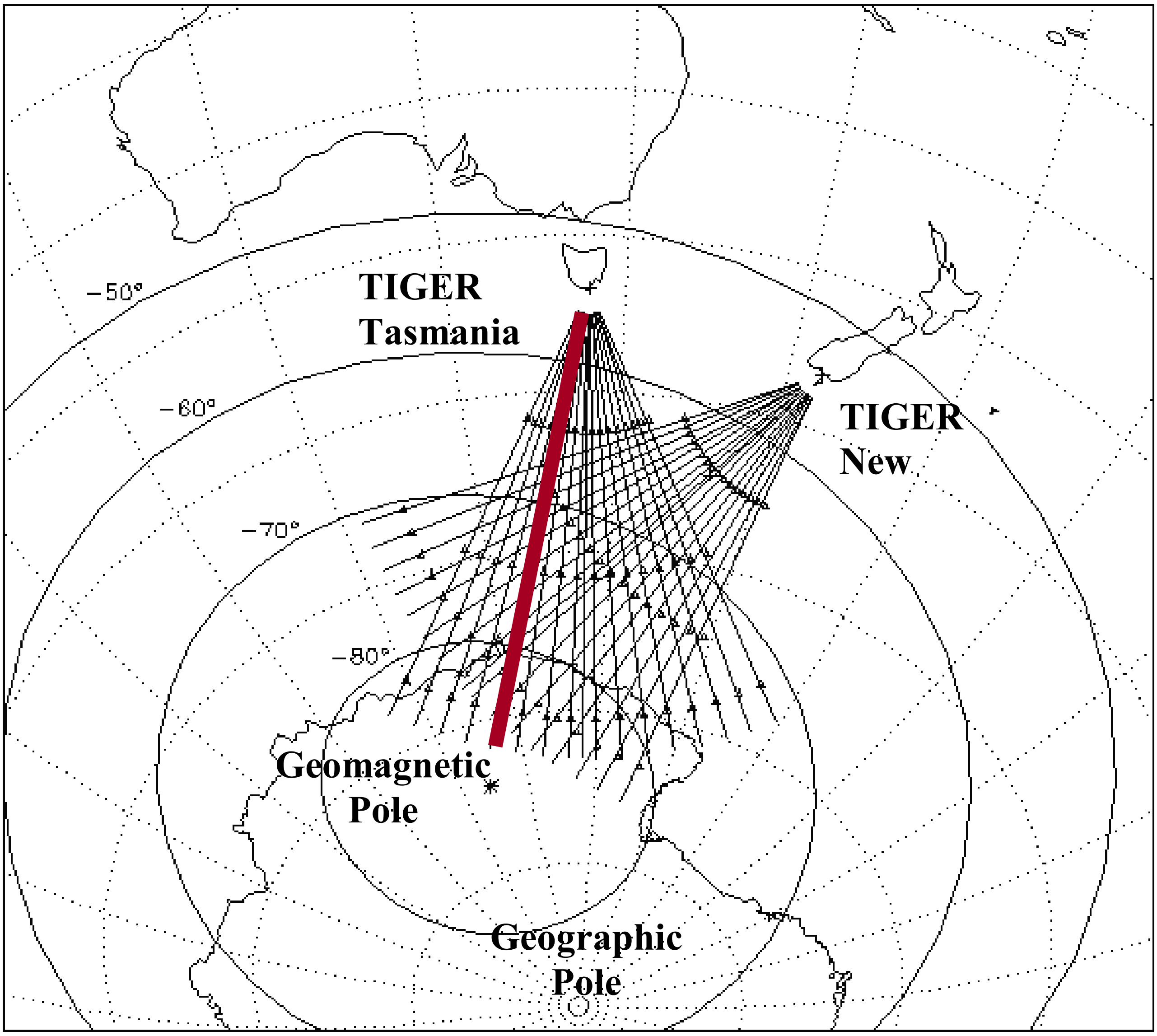


Figure 1: The TIGER radar beams. Beam 4 of the Tasmanian TIGER radar was used to obtain the swept-frequency backscatter ionograms.

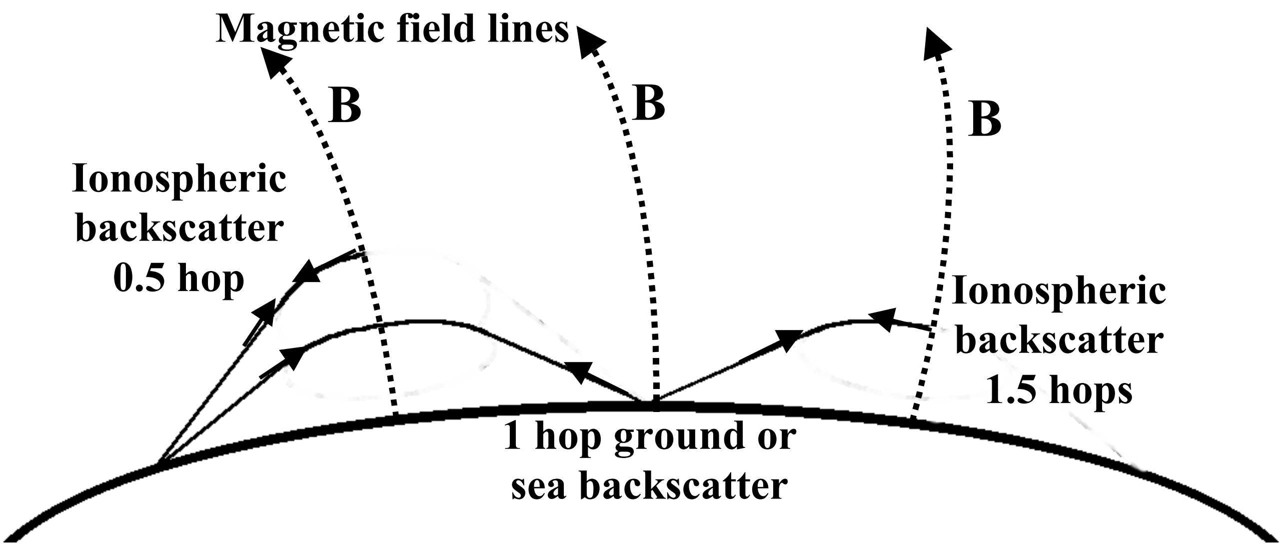


Figure 2: Schematic illustrating some of the ray paths that can give rise to radar echoes.

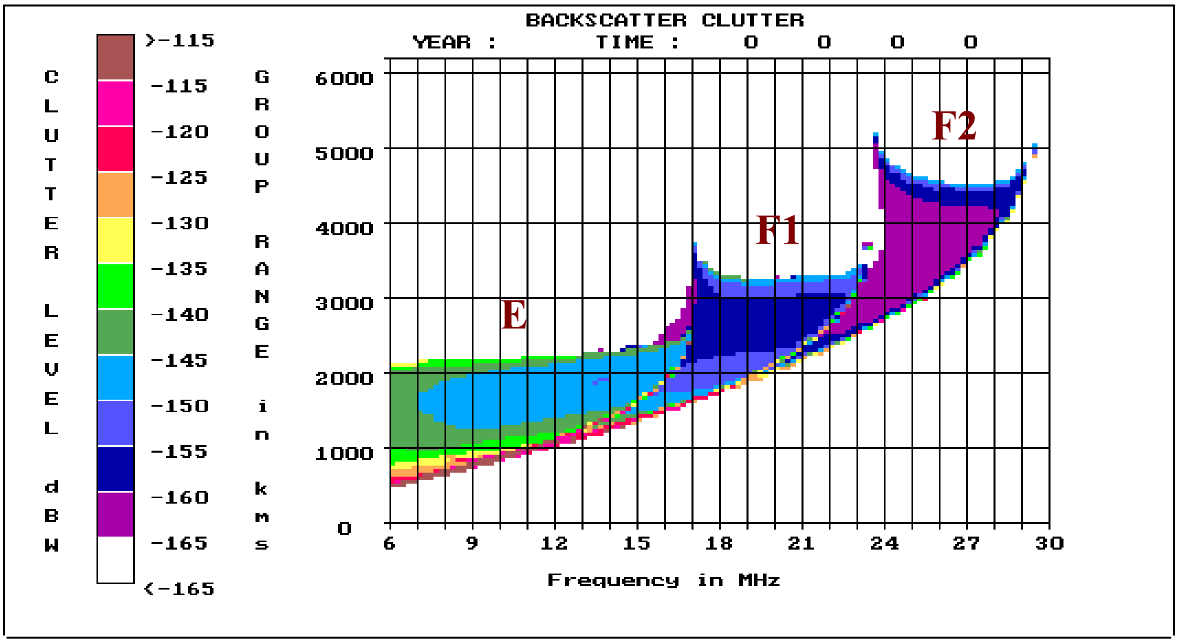


Figure 3: Simulated swept-frequency backscatter ionogram.

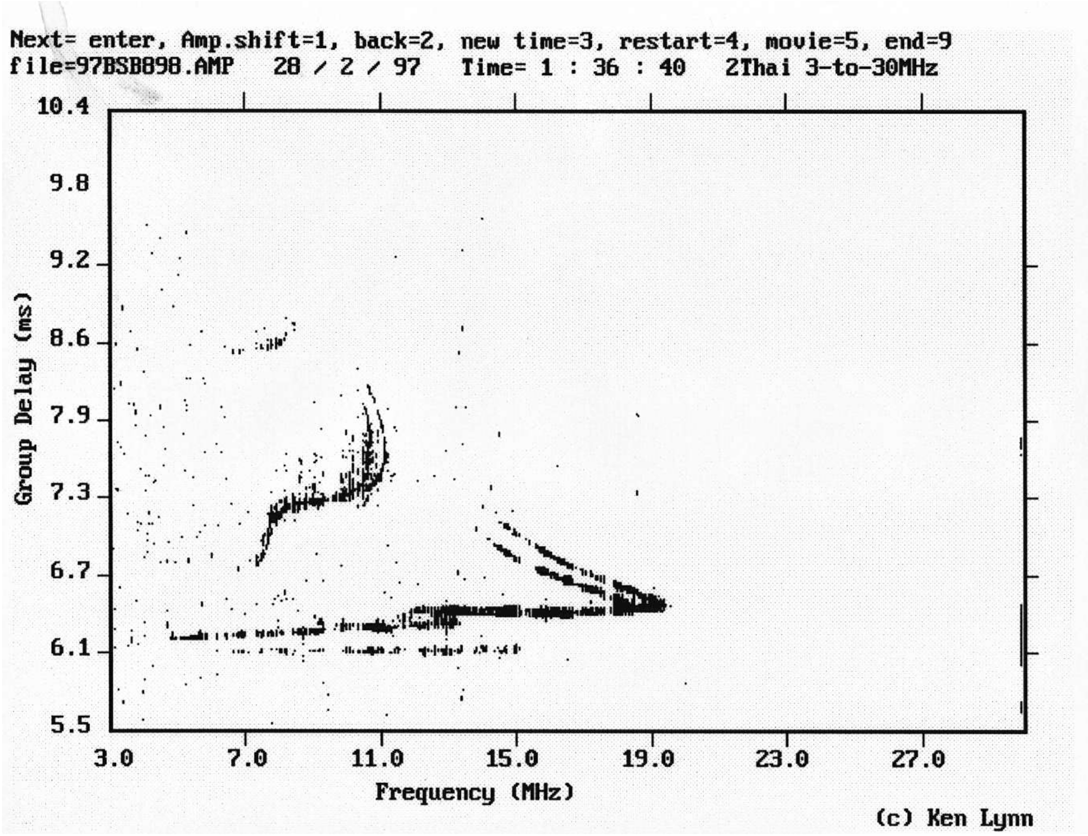


Figure 4. Example of an oblique ionogram (Courtesy Dr Ken Lynn).

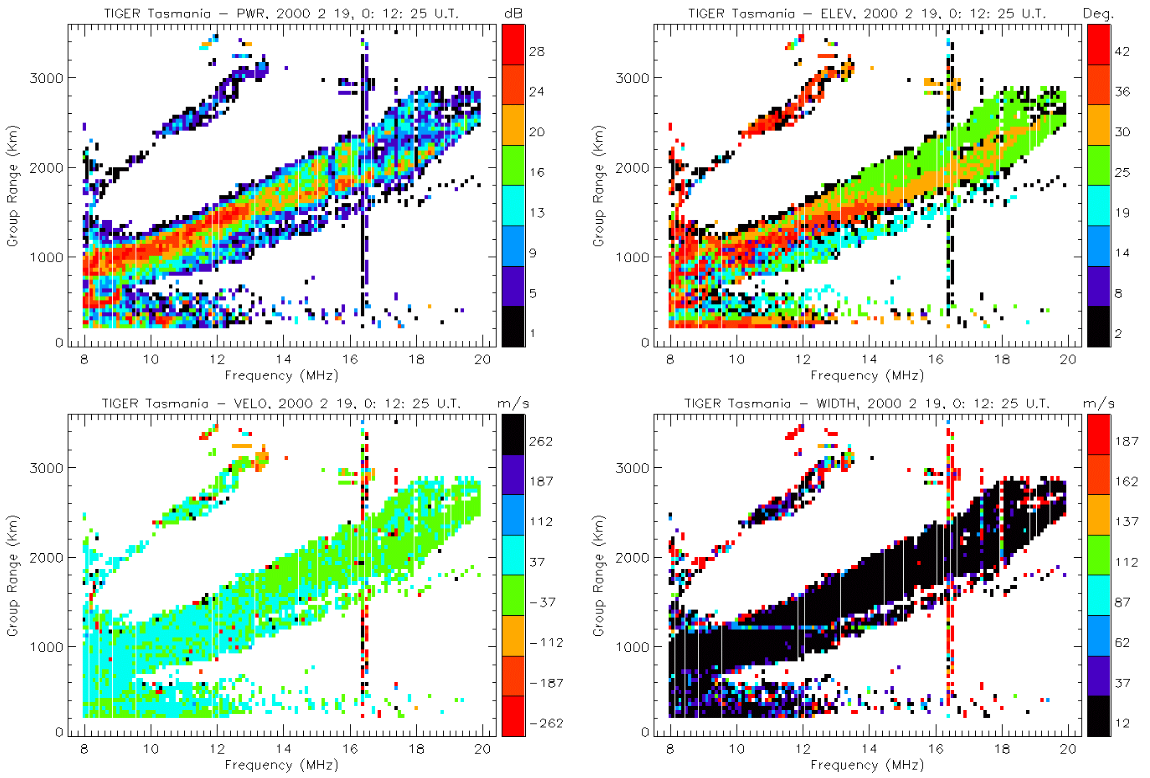


Figure 5. TIGER Backscatter ionogram recorded 0012 UT (1012 LT) 19 February 2000.
Top Left: Echo Power Contours **Top Right:** Elevation Angle Contours
Bottom Left: Echo Velocity Contours **Bottom Right:** Spectral Width Contours

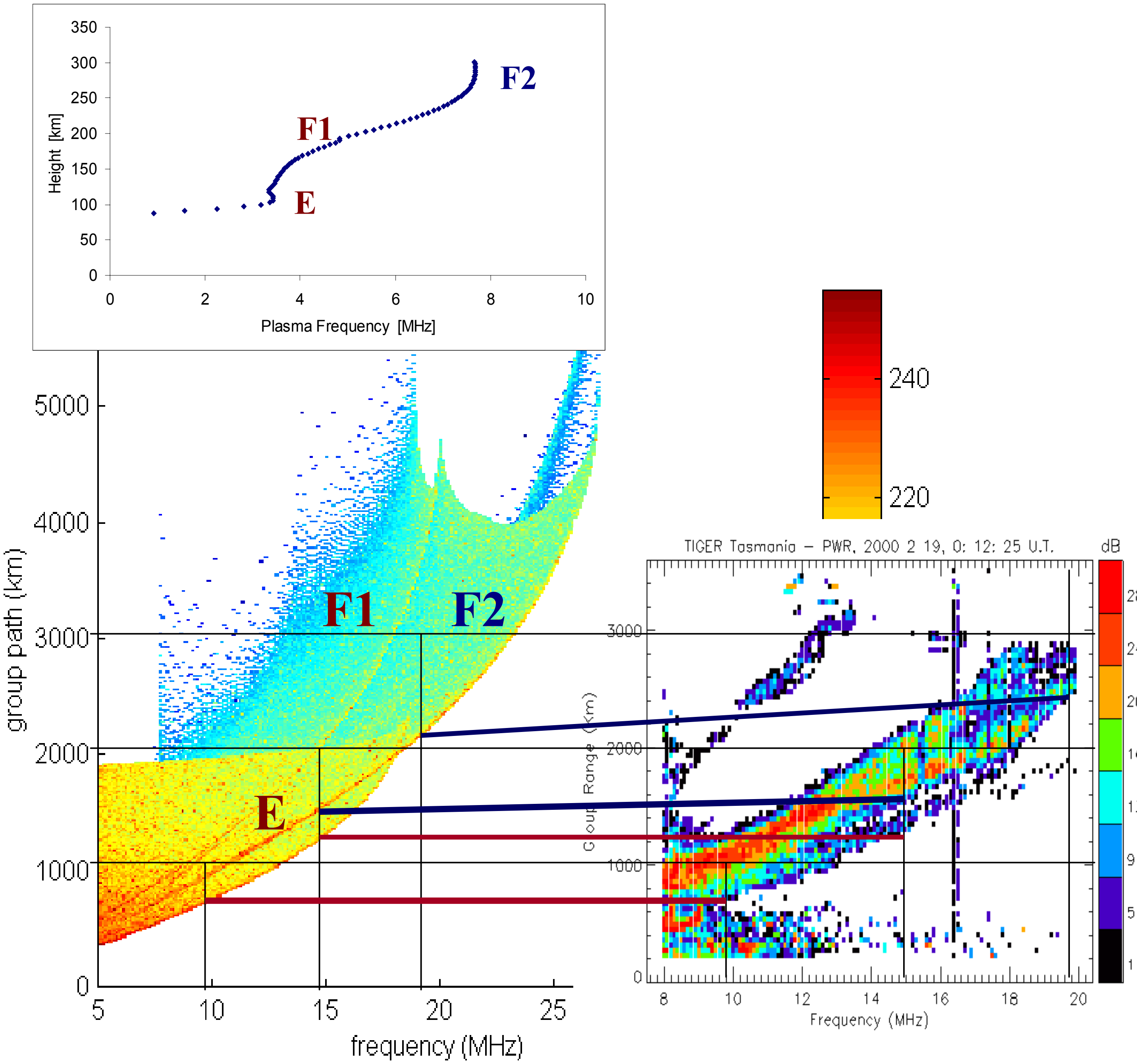


Figure 6. Ionospheric profile from IRI (top left), TIGER backscatter ionogram (top right), Simulated backscatter ionogram (bottom). Lines have been added at three frequencies to aid comparison of the predicted and observed leading edges of E and F layer echo traces.

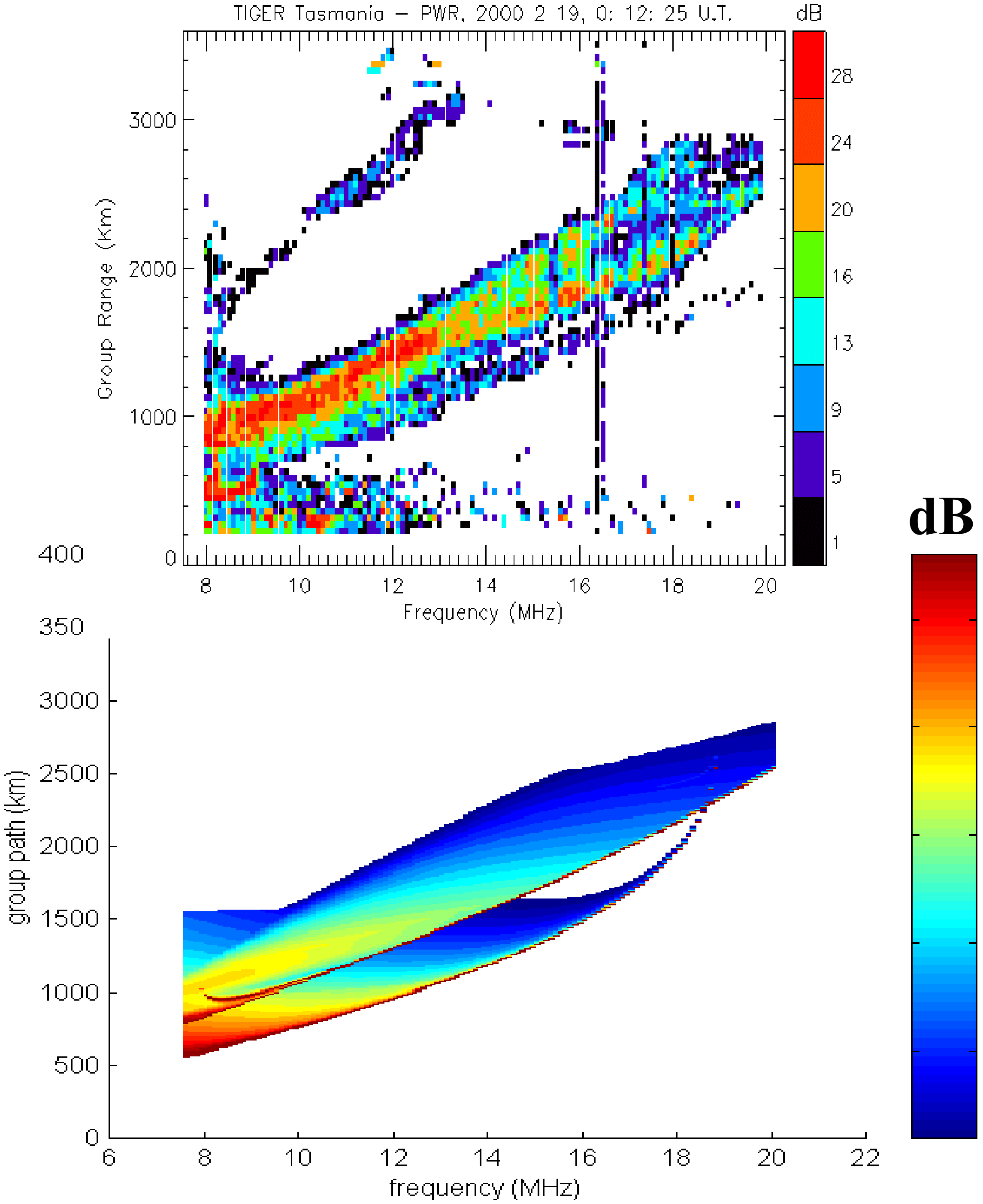
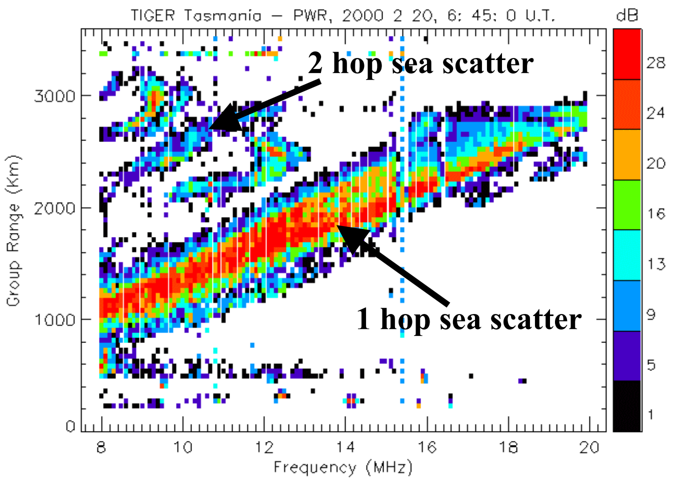


Figure 7. Simulation of backscatter ionogram using IRI model ionosphere and taking account of TIGER antenna patterns and dynamic range.



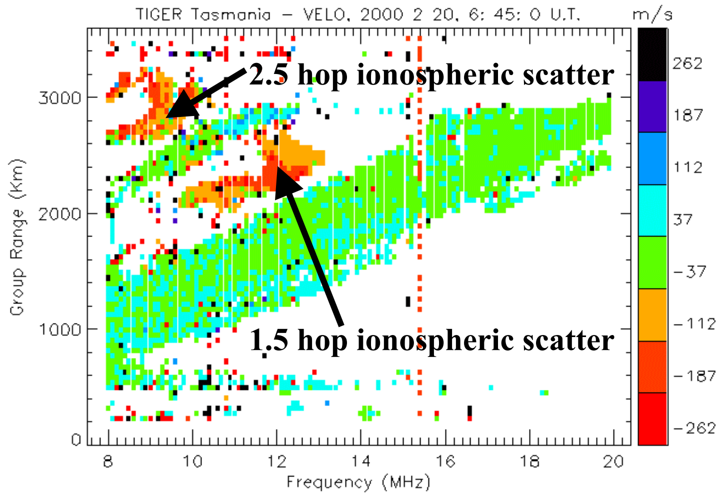


Figure 8. Backscatter ionogram showing one and two hop sea scatter and 1.5 and 2.5 hop ionospheric scatter. Ionogram on left displays echo power, one on right displays echo velocity.

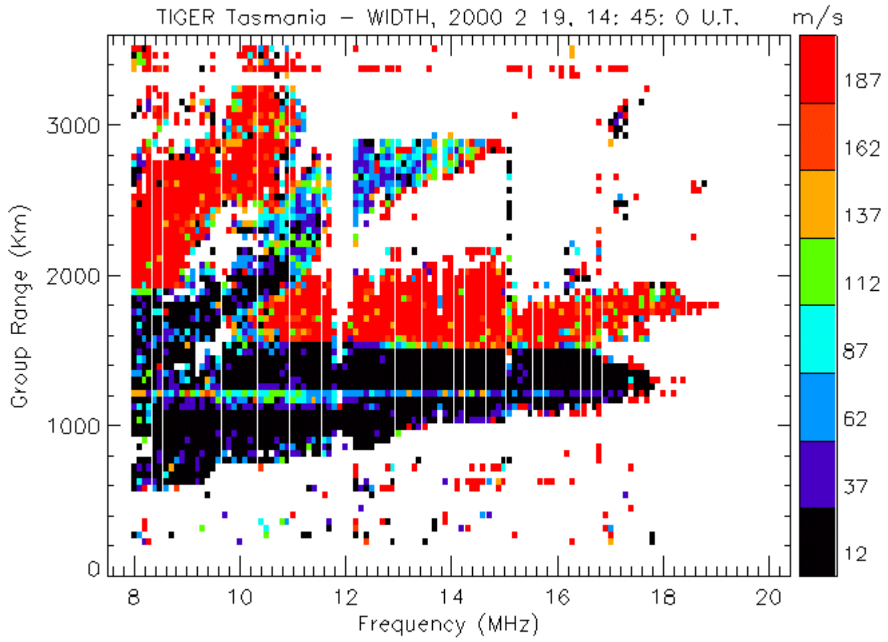


Figure 9. Backscatter ionograms displaying spectral width. Echoes with low spectral width (dark colours) indicate 1 hop sea scatter and echoes with high doppler shift (red) indicate 1.5 hop ionospheric scatter.