Proc. NIPR Symp. Upper Atmos. Phys., 3, 91–95, 1990

HF RADAR EXPERIMENT AT SYOWA STATION FOR THE STUDY OF HIGH-LATITUDE IONOSPHERE—2: A CAPABILITY (EXTENDED ABSTRACT)

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As one of ground-based upper atmosphere observations at Syowa Station (69.0°S, 39.6°E) during the STEP period (1990–1995), we have proposed an HF radar experiment for exploring the high-latitude ionosphere (OGAWA *et al.*, 1989). A usefulness of an HF radar for studying plasma convection in the polar cap, cleft and auroral regions, and irregularity production and dissipation mechanisms have been already demonstrated with the HF radars at Goose Bay in Canada (53.4°N, 60.4°W) and Halley Bay in Antarctica (75.5°S, 26.7°W) established in 1983 and 1988, respectively, and other radars (GREENWALD *et al.*, 1985; DUDENEY, 1988; BAKER *et al.*, 1989). This short note following a previous paper by OGAWA *et al.* (1989) describes briefly a capability of the proposed Syowa Station HF radar.

The Syowa Station HF radar can observe a wide area of the *E*- and *F*-region ionosphere over the Antarctic Continent. In order to detect backscattered echoes from field-aligned ionospheric irregularities, radar wave vectors must be nearly perpendicular (between 89° and 91°) to the geomagnetic field. We calculated the propagation path of an HF wave emitted from Syowa Station to find the region (radar range and altitude) where perpendicularity condition is achieved. The results appear in Fig. 1a, b, c for wave frequencies of 10, 15 and 20 MHz, respectively. We assumed a Chapman-type ionospheric electron density distribution with a maximum density of $3\times10^5/\mathrm{cm}^3$ at 250 km and a scale height of 50 km. As is shown in Fig. 1a, only the waves with elevation angles (*EL*) larger than 25° can penetrate into the topside ionosphere, and the positions (the cross marks) where the radar wave vector makes angles between 89° and 91° with the geomagnetic field are located at ground ranges of 80–1000 km only for $17°\leq EL\leq 33°$. Also noted is that the cross marks at distant ranges exist at the *F*-region altitudes. In the case of Fig. 1b (frequency = 15 MHz), the cross marks appear at ground ranges of 80–1700 km only for $11°\leq EL\leq 23°$. For a frequency of 20 MHz (Fig. 1c), the ground and *EL* ranges become 80–2000 km and $3°\leq EL\leq 19°$, respectively. Thus it is clear that a detection of radar echoes at distant

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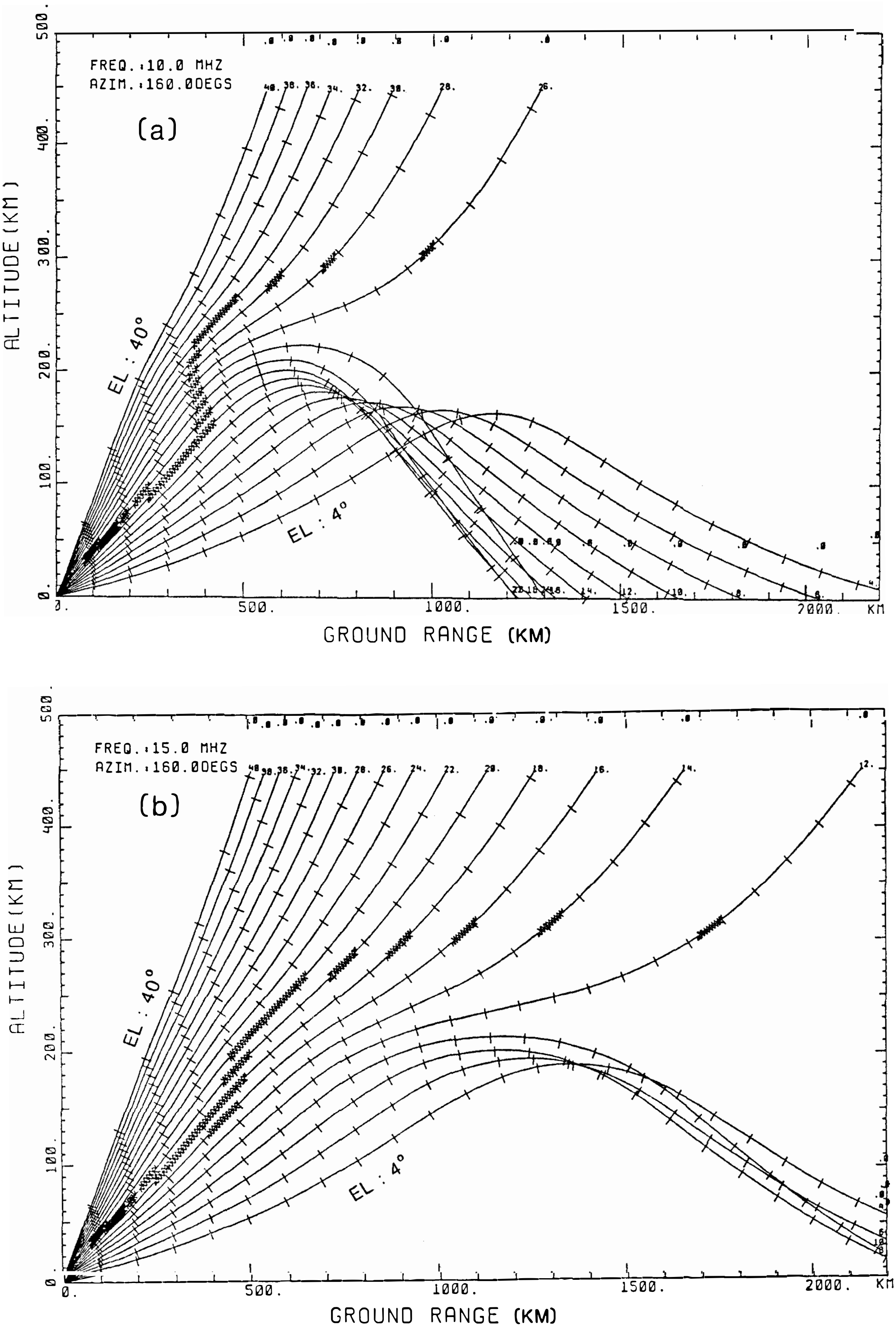

FREQ.:10.0 MHZ
AZIM.:160.00EGS
(a)
ALTITUDE (KM)
GROUND RANGE (KM)
EL : 40°
EL : 4°
0.
100.
200.
300.
400.
500.
1000.
1500.
2000.
KM
FREQ.:15.0 MHZ
AZIM.:160.00EGS
(b)
ALTITUDE (KM)
GROUND RANGE (KM)
EL : 40°
EL : 4°

Fig. 1.

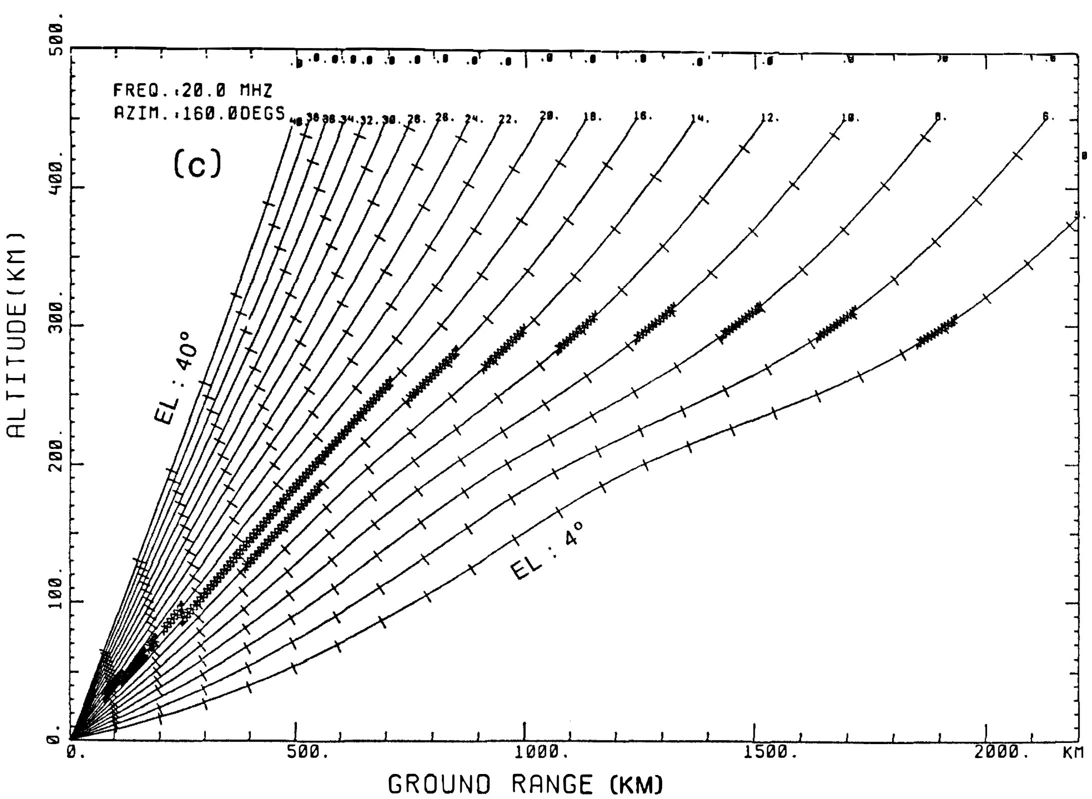

Fig. 1. Ray-tracings for three waves, (a) 10 MHz, (b) 15 MHz and (c) 20 MHz, emitted from Syowa Station with elevation angles of 4°–40° (2° step) at an azimuth of 160°. Positions where ray paths are nearly perpendicular (between 89° and 91°) to the geomagnetic field are indicated by the crosses. A Chapman-type ionospheric electron density distribution is assumed for the calculations.

ranges from Syowa Station requires a higher HF frequency and an antenna beam with lower elevation angle. In real situations, the places satisfying perpendicularity condition are variable with time and space because the high-latitude ionosphere is highly changeable, especially during disturbed conditions.

By changing the azimuth angle of an emitted wave, we also calculated the echo areas of the 10, 15 and 20 MHz waves which can be observed from Syowa Station. The results are displayed in Fig. 2 by shaded patterns. The *E*-region echoes, which can be detected by the Syowa Station VHF radar (IGARASHI *et al.*, 1982), appear at shorter ranges than the *F*-region echoes (see Fig. 1). This is the reason why we must use HF waves to explore the polar cap and cleft regions at very high latitudes.

The field of view (about 50° in azimuth and 2000 km in range) of the proposed Syowa Station HF radar is represented in Fig. 2 by a wedge pattern. Also shown is the field of view of the Halley Bay HF radar operated by the British Antarctic Survey. A two-dimensional horizontal plasma flow can be derived for the overlapping fields of view from the Syowa Station and Halley Bay radars. The overlapping area may expand or shrink depending on the ionospheric electron density distribution which is very sensitive to geomagnetic activity.

An ionospheric volume illuminated by the Antarctic twin radars is geomagnetically connected with that over Greenland which is investigated with the Arctic twin HF

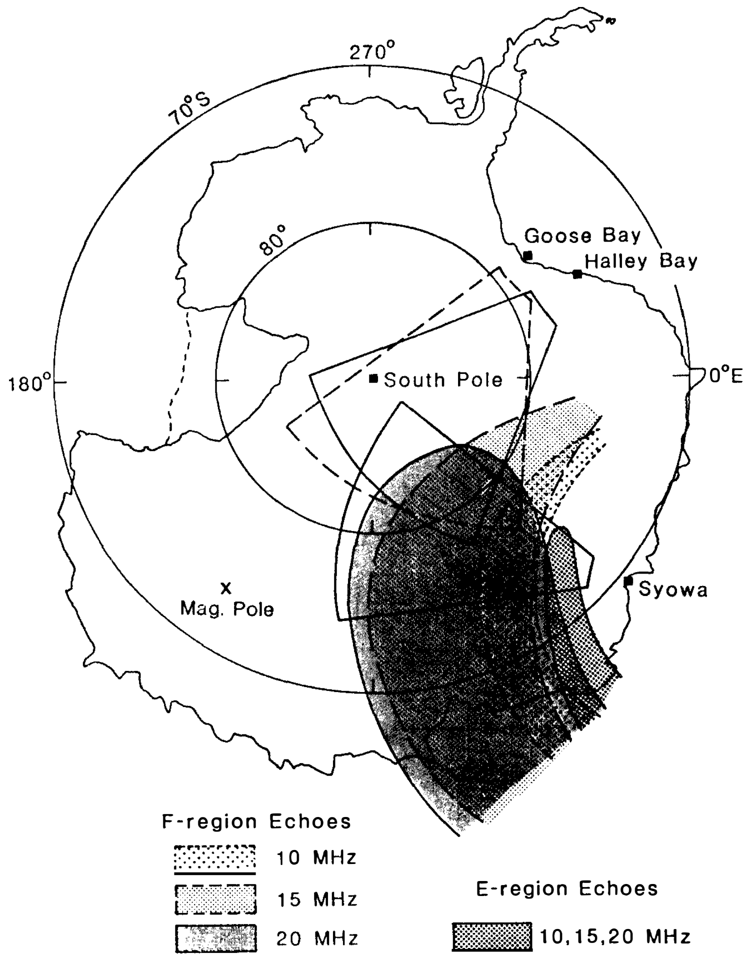

Fig. 2. Echo areas for three wave frequencies (10, 15 and 20 MHz) seen from the Syowa Station HF radar. Fields of view of the proposed Syowa Station HF radar and the Halley Bay HF radar are indicated by a solid wedge. Goose Bay HF radar field of view mapped onto the Antarctica is also shown by a broken wedge.

radars located at Goose Bay and Schefferville in Canada (GREENWALD *et al.*, 1985). The Goose Bay radar field of view mapped onto the Antarctica is shown in Fig. 2 by a broken wedge. Conjugate observations of plasma convection and irregularities are quite important for understanding similarities and dissimilarities of the phenomena between the both hemispheres and for diagnostics of the magnetosphere and interplanetary space (BAKER *et al.*, 1989). It is noted that the conjugate point of the Sondre Stromfjord IS radar is located in the overlapping area. Thus we believe that the Syowa Station HF radar can contribute greatly to a further understanding of the physical processes occurring in the high-latitude ionosphere.

We are planning to start our HF radar experiment at latest in early 1993. Radar and software systems will be very similar to ones at Goose Bay and Halley Bay, enabling us to compare easily the data from three radars. Moreover a computer network is under consideration for real-time transmission from Syowa Station to Japan to achieve easier and faster data exchange in the HF radar community. It is highly possible that fruitful scientific results will come out through an international cooperation among the related HF radars.

Acknowledgments

We would like to thank Drs. R. A. GREENWALD and K. B. BAKER of the Applied Physics Laboratory (APL), Johns Hopkins University and Dr. J. R. DUDENEY of the British Antarctic Survey for valuable discussions and suggestions during the feasibility study of the Syowa Station HF radar. Ray-tracing results of HF waves were kindly supplied by Dr. A. FREY of APL.

References

BAKER, K. B., GREENWALD, R. A., RUOHONIEMI, J. M., DUDENEY, J. R., PINNOCK, M., MATTIN, N. and LEONARD, J. M. (1989): PACE; Polar Anglo-American conjugate experiment. EOS; Trans. Am. Geophys. Union, **70**, 785–799.

DUDENEY, J. R. (1988): The polar Anglo-American conjugate experiment. EOS; Trans. Am. Geophys. Union, **69**, 1347.

GREENWALD, R. A., BAKER, K. B., HUTCHINS, R. A. and HANUISE, C. (1985): An HF phased-array radar for studying small-scale structure in the high-latitude ionosphere. Radio Sci., **20**, 63–79.

IGARASHI, K., OGAWA, T., OSE, M., FUJII, R. and HIRASAWA, T. (1982): A new VHF Doppler radar experiment at Syowa Station. Mem. Natl Inst. Polar Res., Spec. Issue, **22**, 258–267.

OGAWA, T., IGARASHI, K., HIRASAWA, T., EJIRI, M. and FUJII, R. (1989): HF radar experiment at Syowa Station for the study of high-latitude ionosphere; A proposal. Proc. NIPR Symp. Upper Atmos. Phys., **2**, 139–140.

(Received September 12, 1989; Revised manuscript received October 31, 1989)