ENHANCED BEAM STEERING CAPABILITIES FOR THE TIGER SUPERDARN RADARS

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Abstract

The two Tasman International Geospace Environment Radars (TIGER) are the Australian contribution to the international Super Dual Auroral Radar Network (SuperDARN) which contains many HF over-the-horizon radars in both hemispheres. The first radar is located on Bruny Island Tasmania and the new Unwin radar is located near Invercargill on the South Island of New Zealand. SuperDARN radars use a phased array of 16 transmit/receive antennas and 4 receive only interferometer antennas. Beam steering is performed by an analogue phasing matrix with 16 fixed beams separated by 3.24° and covering a field of view of approximately 52°.

Three new phasing boxes which add additional time delays to the signals sent to each antenna of a phased array have been built by La Trobe University to increase the field of view of the TIGER SuperDARN radars. The first phasing box, designed to rotate the field of view of the Bruny Island radar to view over Macquarie Island, has been used to gather data for comparison with instruments located on Macquarie Island. The second phasing box was designed to rotate the field of view of the Bruny Island radar to the magnetic conjugate point of the High Frequency Active Auroral Research Program (HAARP) ionospheric heater near Gakona, Alaska. The third phasing box was designed to rotate the Unwin radar field of view to observe F-region scatter above the E-region scatter observed in the nearest range gates of the Bruny Island radar and has been placed on Channel B of the Unwin radar to allow for continuous operation during common time.

1 Introduction

The two Tasman International Geospace Environment Radars (TIGER) [Dyson *et al.* 2003] are a component of the international Super Dual Auroral Radar Network (SuperDARN) of coherent scatter HF phased array radars dedicated to ionospheric research [Greenwald *et al.* 1995]. SuperDARN radars rely on refraction of HF radio waves to detect field-aligned decametre scale irregularities in the ionosphere [Greenwald *et al.* 1995]. SuperDARN radars have 16 transmit/receive antennas and a 4 antenna receive only interferometer array with an analogue phasing matrix used to select which of 16 beams separated by 3.24° is used.

In this paper the scientific applications of a device which can rotate the field of view of a SuperDARN radar by applying phase shifts in addition to what the phasing matrix provides is described. This device increases the flexibility of radar operations to support scientific studies which would be otherwise impossible without the extended field of view [Healey 2005].

2 Design

For a linear phased array the time delay for a given array element required to rotate the main lobe is $t_d = \frac{d\sin(\theta)}{c}$ where t_d is the time delay, d is the distance along the length of the array and θ is the beam steering angle desired.

The fact that the time delays for a given angle are frequency independent for a linear array means that fixed time delays are suitable for steering the beam of a SuperDARN radar. A phasing matrix using long lengths of cable to delay the signals to each antenna is used to select between 16 beams separated by 3.24° to cover the field of view of 52°.

The phasing boxes used to rotate the fields of view are connected in series with the phasing matrix and contain solid state delay lines providing the calculated delay required for each antenna along with a control circuit to switch the delay lines in or out of the signal path (Figure 1). A phasing box can be built for approximately $5 000.

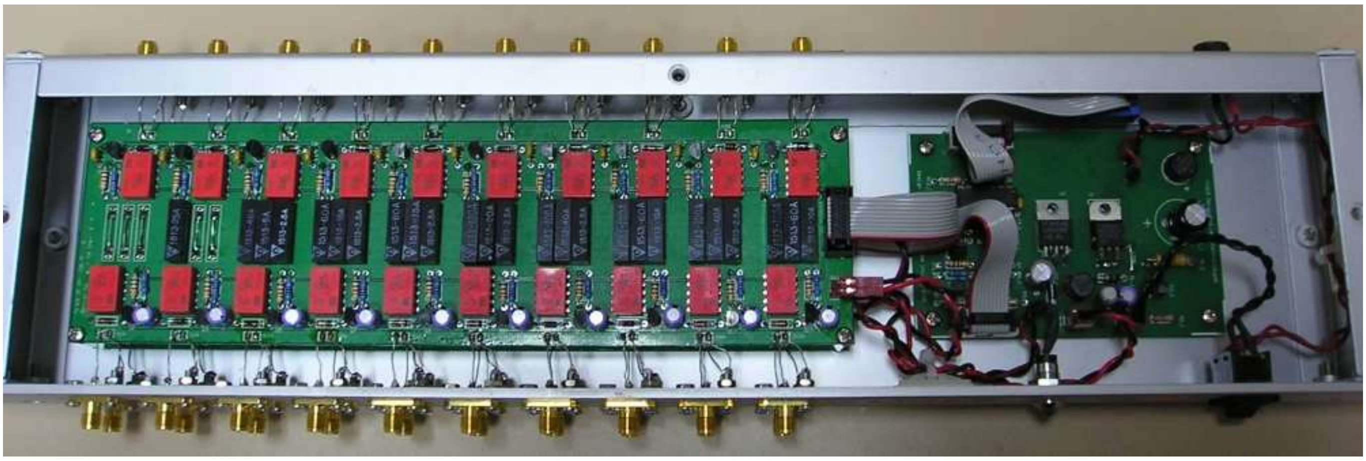

Figure 1: The inside of the HAARP phasing box showing the solid state delay lines (black) for ten of the antennae with the logic circuit on the right

3 Experiments

3.1 Macquarie Island

The Australian Antarctic Division station on Macquarie Island contains basic space science instruments including magnetometers, an auroral imager, a digital ionosonde and a riometer. Macquarie Island is outside the field of view of the Bruny Island radar but underneath beam 12 of the Unwin radar.

The first phasing box built is used to move beam 14 of the Bruny Island radar over Macquarie Island (Figure 2) to obtain 2D ionospheric wind measurements over Macquarie Island for comparison with measurements made by instruments on Macquarie Island.

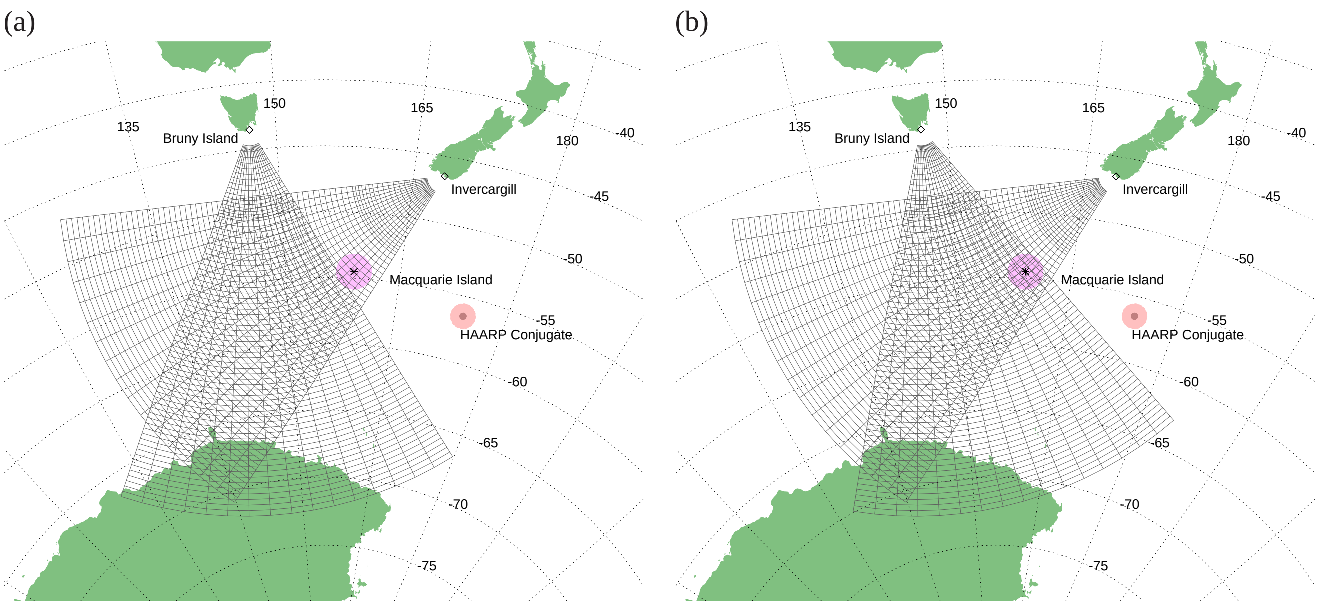

Figure 2: (a) The radar fields of view with no phasing box in use. (b) The radar fields of view with the Macquarie Island phasing box in use

3.2 *HAARP*

The High Frequency Active Auroral Research Program (HAARP) in Gakona, Alaska is a powerful radio transmitter which heats the ionosphere to stimulate the growth of ionospheric irregularities. The magnetic conjugate point of HAARP is in the Southern Ocean.

The second phasing box is used to move beam 12 of the Bruny Island radar over the HAARP conjugate point (Figure 3a). Some preliminary searches for conjugate effects have been made, but more campaigns must be run to detect or rule out conjugate effects.

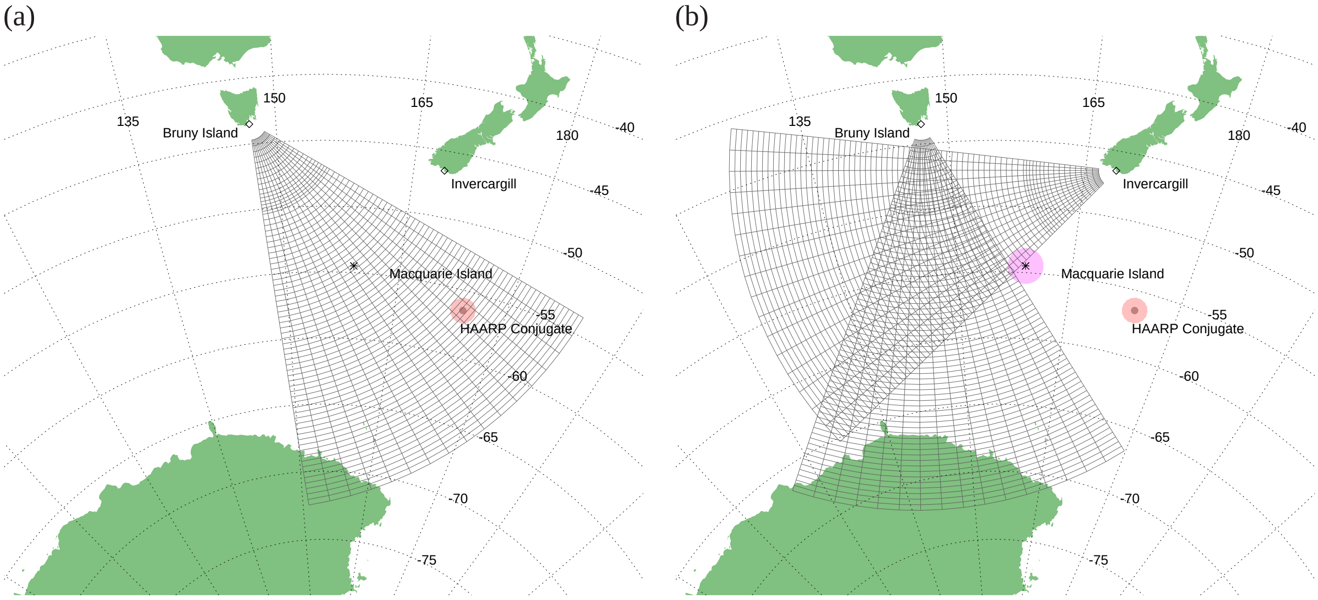

Figure 3: (a) The field of view of the Bruny Island radar with the HAARP phasing box in use. (b) The radar fields of view with the E-F region phasing box in use. The default radar fields of view were shown in Figure 2a

3.3 *E-F Region*

SuperDARN radars typically detect scatter from F Region irregularities but the nearest range gates often detect scatter from E Region irregularities. There have been very few studies of large scale convection in both the E and F Regions making our knowledge of the relationship between the two regions contingent on measurements made at different locations.

The third phasing box is connected to the second channel of the Unwin radar and is used to allow the Unwin radar to detect F Region scatter above E Region scatter detected by the Bruny Island radar (Figure 3b). Because the Unwin radar is a stereo radar it is possible to run a scan mode using the phasing box without interrupting routine operations thereby allowing for the acquisition of a large database of observations from both Regions along the same field line.

4 Limitations

The sidelobes of the beam of a phased array typically get worse the further away the beam is steered from the array broadside and SuperDARN radars are no exception.

The sidelobes tend to appear at higher frequencies before appearing at lower frequencies making higher frequencies less useful when steering to large off-broadside angles.

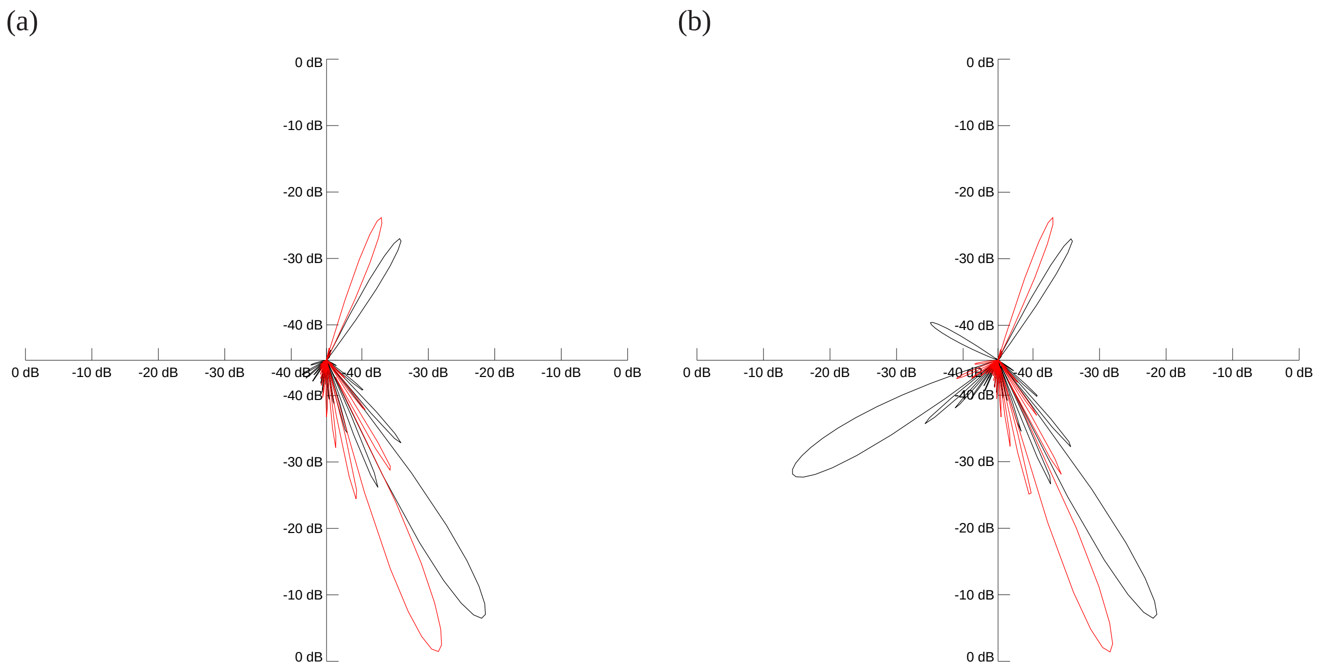

Figure 4: Simulated antenna patterns along beam 14 with the Macquarie Island phasing box off (red) and on (black). (a) is with a frequency of 12 MHz and (b) is with a frequency of 14 MHz. Notice the sidelobe which appears at 14 MHz with the phasing box on. Details are in [Healey 2005].

Figure 4 shows that a -10 dB sidelobe appears at 14 MHz when using the Macquarie Island phasing box which requires campaigns using the Macquarie Island phasing box should not use frequencies much more than 12 MHz. The E-F Region phasing box provides slightly more field of view rotation and on the edge beam suffers from a -20 dB sidelobe even at 12 MHz which is considered tolerable.

The HAARP phasing box provides the largest field of view rotation and suffers from quite severe sidelobes at even 12 MHz. This limits use of the HAARP phasing box to 11 MHz or below. However if a correlation were found between what was happening at HAARP and what was detected by TIGER Bruny Island it would be possible to conclude that the signature was detected in the main lobe regardless of frequency.

5 Conclusion

A low cost method of increasing the scientific capabilities of SuperDARN radars has been developed, tested and is being put to use. To minimise the effects of large sidelobes frequencies lower than what the radar is capable of transmitting need to be used although the radar normally operates at the phasing box safe frequencies.

References

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