Using a DPS as a Coherent Scatter HF Radar

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Abstract

Coherent backscatter is routinely observed in the polar ionosphere using the SuperDARN HF Radar network. The Digisonde Portable Sounder (DPS) routinely measures ionospheric reflections to form ionograms at all latitudes. The DPS can be configured in the Drift mode which allows the determination of the full Doppler Spectrum for each echo. The DPS was configured in the Drift mode to try and observe ionospheric backscatter at mid to low latitudes. The experiment yielded two distinct ranges of scatter, one that appears to be groundscatter and the other is not.

1. Introduction

The Digisonde Portable Sounder (DPS) located at Grahamstown (33.3S, 26.5E) was configured to try and observe ionospheric backscatter. In order to avoid confusion we will define the nomenclature for the different types of echoes to be used in this discussion. An ionosonde will create an ionogram by transmitting at frequencies below foF2 and then by recording the time of flight of the signal, the range of the layer of the ionosphere that reflected the signal can be determined. These types of echoes will be called *ionospheric reflections*. Echoes can also be recorded for signals above foF2. These echoes will be divided into two types, *groundscatter* echoes and *ionospheric backscatter*. Ground and ionospheric backscatter are routinely used by SuperDARN HF Radars to observe the movement of ionospheric irregularities in the polar cap ionosphere. This paper reports on the results of this experiment and shows that DPS systems can be used to observe ionospheric backscatter much similar to the SuperDARN HF radar system.

2. The SuperDARN radar

A SuperDARN HF radar [1] uses ionospheric field aligned irregularities as its targets. In the polar ionosphere these irregularities will have a periodic structure. If the ray path of the signal is orthogonal to this structure and the periodicity is such that the scatter is constructive, then sufficient signal will be reflected back to the transmitter [2]. The time of flight of the signal is recorded to determine the range of the target. In order to determine the velocity of the targets, a staggered pulse pattern is transmitted and an autocorrelation function (ACF) is determined for each range. The ACF is fitted with a mathematical function that uses signal power, Doppler shift and spectral width as parameters. The parameters that yield the best fit are then stored as the received power, Doppler velocity and spectral width for that range.

3. The Digisonde

The Grahamstown DPS forms part of the South African Ionosonde Network. There are three DPS systems that routinely make vertical incidence soundings and produce ionogram that are automatically scaled by the Lowell Artist software. Although the DPS in Grahamstown is configured primarily as a vertical incidence sounder, some of the radiation is transmitted off-vertical. When the sounding frequency is above foF2 (foF2 is the maximum frequency that will be *reflected* in the ionosphere) some of the signal is refracted through the ionosphere into space while that which is radiated above a critical zenith angle will undergo total internal refraction in the ionosphere will be reflected back down to the earth at some remote distance.

The DPS will make a time series of pulses during what is known as a coherent integration time (CIT). After each pulse is transmitted the receiver is sampled and the data are stored in range bins. At the end of the CIT the time series for each range bin are Fourier Transformed to yield a Doppler Spectrum for each sampled range. Once the CIT is complete, the DPS can increment the sounding frequency to create an ionogram or it can repeat with the same sounding frequency thus creating a fixed frequency sounding. When operating in the vertical incidence mode the DPS will store the maximum amplitude for each sampled range and then ignore the full Doppler information. In the drift mode the DPS will store the full Doppler spectrum but only for a limited number of ranges.

4. The Digisonde setup for the experiment

The Digisonde was set to perform two different types of drift measurements, namely a vertical incidence type sounding and a fixed frequency sounding.

4.1 Drift vertical incidence sounding (Drift Ionogram)

For the drift vertical incidence sounding, the Digisonde started its sounding program at a frequency below fmin (fmin is the minimum frequency *reflected* by the ionosphere), and incremented the sounding frequency in steps of 100kHz until some value above foF2. The full Doppler spectra were stored for three ranges at each frequency. The limitation of the number of heights was required because increasing the number of heights would mean more data for each frequency step would have to be written to disk. The current system is limited by its disk write speed and so more data would increase the overall sounding time of the program.

4.2 Drift fixed frequency sounding

For the next two hours after the drift vertical incidence sounding, the Digisonde was configured to perform a series of fixed frequency drift scans at a frequency of 9.05MHz. 9.05MHz was chosen as it was above foF2 for the entire duration of the experiment. Each scan was set to last 4 minutes at regular spaced intervals in the two hour period. These time limitations are due to the fact that the DPS must run a standard vertical incidence sounding every 15 minutes as part of the obligations of the facility.

In a fixed frequency scan the Digisonde will perform multiple coherent integrations for the same frequency. This will allow the determination of the most probable range that the 9.05MHz signal will be scattered from.

5. Analysis of the fixed frequency scatter

5.1 The data

The results for the fixed frequency sounding show that there are two significantly different regions of scatter. There is scatter from an average of 824.23±65.54 km which is consistent with where 9.05MHz was scattered in the drift ionogram and there is also scatter at a range of an average of 138.72±23.97km.

5.2 Spectral analysis

To determine the cause for this separation in scatter we decided to split the scatter into two groups, scatter from closer that 500km and scatter form further than 500km. An analysis of the spectra for the echoes from the two regions shows that the peak of the line of sight Doppler spectrum for the scatter from above 500 km is centred around zero while that from less that 500km is separated from the zero line.

It has been shown [3] that groundscatter echoes in the SuperDARN coherent radar system are characterised by narrow spectral widths with zero Doppler shift in the spectrum. The fact that all of the echoes from above 500km have spectra with a peak closed to zero is evidence that these may indeed be groundscatter echoes. The peaks in the spectra for the echoes from the nearer ranges are not clustered around zero, probably indicating that this is not groundscatter.

5.3 Range analysis

The Drift Ionogram contained a linear increase in range with frequency for the echoes above foF2. This is characteristic of what Croft calls the leading edge of Sky-wave backscatter [4]. This is further evidence that the scatter from above 500km is indeed groundscatter.

Using a set of equivalence relationships for a plane earth-ionosphere system [5], it is possible to determine the smallest zenith angle that would give total internal ionospheric refraction for a signal transmitted above foF2. The secant law

$$f_0 = f_v \sec\theta,$$

where f_0 is the sounding frequency, f_v is the equivalent vertical frequency and θ is the zenith angle, gives, using f_0 = 9.05MHz, and f_v = 5.825MHz, that smallest zenith angle is 49.94º. Martyn's theorem then allows one to determine equivalent path of an oblique signal with

$$P'(f_0) = 2h'(f_v)\sec\theta,$$

where $h'(f_v)$ is the virtual height of the equivalent vertical frequency and θ is the zenith angle. In order to determine the shortest possible range for a ground scattered signal for a f_0 of 9.05MHz we used f_v of 5.825MHz and an $h'(f_v)$ of 230km giving a shortest path of 296km, well above the 134km average range of the ionospheric backscatter. This shows that it is not possible for the echoes from below 200km to be groundscatter

6. Conclusion

The DPS can indeed be configured to observe backscatter. There is evidence that the scatter observed from 800km appears to be groundscatter. Scatter was also observed from ranges below 200km. Although this scatter does not appear to be groundscatter there is no evidence from this experiment that it is coherent scatter from ionospheric field aligned irregularities as is the case with the SuperDARN HF radars. Further experiments are planned to accurately determine the nature of this ionospheric backscatter.

7. References

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