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ELF/VLF waves of magnetospheric and terrestrial origin: 16 years of continuous observations in Antarctica

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This paper analyses a unique set of continuous high-quality well-calibrated observations of ELF/VLF radio waves (0.3 – 10 kHz) made at Halley Research Station, Antarctica (75S, 27W, L=4.3) over one and a half solar cycles (1992 – 2007). Reference is also made to similar but shorter data sets obtained from a network of Automatic Geophysical Observatories (AGOs) between Halley and South Pole. The observed waves vary over a very wide dynamic range, from the receiver noise level of ~20dB wrt $10^{-33}T^2Hz^{-1}$ (at 1 kHz) up to 40-50 dB above it. However, the long continuous data set allows us to average out the random and aperiodic variations to extract the underlying dependence of the wave characteristics on local time, time of year, solar cycle, etc. Below about 5 kHz the waves are predominantly natural whistler mode waves, notably chorus, which are generated near the equatorial plane of the magnetosphere and propagate on geomagnetic field-aligned ("ducted") paths to both hemispheres. The magnetospheric source function is convolved with a propagation function which represents passage of the waves from the source region through and under the ionosphere to the receiver. At the lower end of this frequency range the average spectrum has the $1/f$ dependence of magnetospheric waves. The ionosphere is relatively transparent and waves are received from a large volume of the magnetosphere. At Halley the observed intensities are largest in the morning (dawn chorus) and afternoon (midlatitude hiss), and tend to peak at the equinoxes (the Russell-McPherron effect), with the March peak generally a little larger than September. At the middle frequencies of the range, the spectrum drops below the $1/f$ line, due to the larger ionospheric absorption; the waves observed are those propagating close to the Halley field line, and intensities are largest under a dark ionosphere (local night and winter). The average polarisation is elliptical with a sense corresponding to downcoming whistler mode waves in the southern hemisphere (negative ellipticity). At the top of the frequency range (~10 kHz) the observed waves

are mostly subionospherically propagated atmospherics from tropical lightning; the spectrum and dependence on local time and season are determined largely by the lightning source function. The polarisation is predominantly linear.