

## Non-Eckersley-law Whistlers observed at Equatorial Latitudes with Satellite *Injun 3*

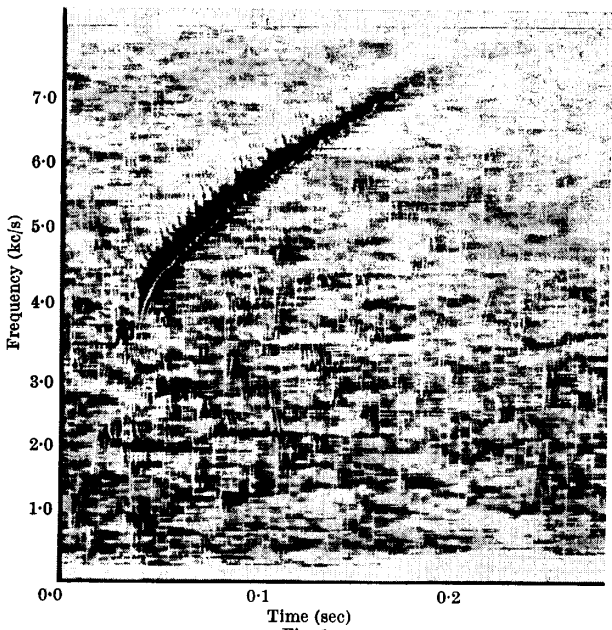
THIS communication reports two new whistlers discovered in the very-low-frequency radio noise data from *Injun 3* satellite. This satellite carried a very-low-frequency receiver with a magnetic loop antenna oriented so as to detect the component of the wave magnetic field which is propagating perpendicular to the geomagnetic field. The pass band of the very-low-frequency receiver was about 0.5-7 kc/s. Altitudes ranging from 237 km to 2,785 km are covered by the *Injun 3* very-low-frequency data.

Frequency-time spectrograms of the two new whistlers are shown in Figs. 1 and 2. A unique feature of these whistlers is that over the observed portion of the frequency spectrum the delay time increases with increasing frequency, thus deviating markedly from the Eckersley law for whistlers (time delay inversely proportional to the square root of frequency). Because of their appearance on a frequency-time spectrogram, we call the whistlers in Figs. 1 and 2 the 'riser' and the 'check whistler', respectively.

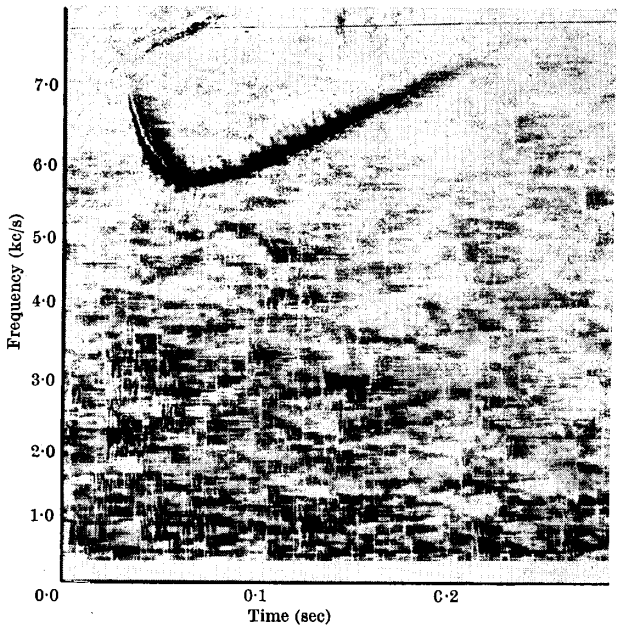
Both the riser and the check whistler have been received simultaneously from two different satellite tracking stations; therefore we are certain that these signals are not caused by interference in the data transmission. We also note that the whistler signals show strong attenuation above 7 kc/s, corresponding to the upper cut-off frequency of the *Injun 3* very-low-frequency receiver<sup>1</sup>. Thus we feel certain that these signals were detected by the loop antenna.

We present the following evidence to substantiate our claim that these events are whistlers. As will be shown, all these events occurred in the vicinity of the magnetic equator at altitudes above 900 km. In the *Injun 3* data, Eckersley-law whistlers are quite regularly observed in this region whereas commonly known types of very-low-frequency emissions are virtually never observed here. Also, a common feature of very-low-frequency emissions is repetition at short intervals<sup>2</sup>. No such repetition is found with the events on which we report. In fact, often only one or two events are found in a 20-min satellite pass.

From the analysis of 20 h of very-low-frequency data a total of seventy risers has been found. All risers observed thus far were received within 23 degrees (magnetic latitude) of the magnetic equator and above 900 km altitude. The majority (80 per cent) of these whistlers



Time (sec)  
Fig. 1



Time (sec)  
Fig. 2

are found within 15 degrees of the magnetic equator and above 2,000 km altitude.

The equatorial very-low-frequency data used for the riser study has yielded six occurrences of the check whistler. All six were received within 23 degrees of the magnetic equator and above 2,000 km altitude.

In considering possible explanations for the riser and check whistler we have eliminated the possibility that these whistlers are nose whistlers<sup>3</sup> because the nose frequencies at these invariant latitudes are at least ten times the frequencies at which we observe these new whistlers. Because waves from equatorial lightning sources received in the ionosphere near the equator are likely to be propagating nearly perpendicular to the geomagnetic field, we believe that the unusual dispersion of the riser and check whistler arises because of the lower hybrid resonance<sup>4</sup>. The lower hybrid resonance frequency can range between 3 and 8 kc/s in the region of the ionosphere at which we observe these whistlers.

This work was supported in part by an Office of Naval Research contract. One of us (S. D. S.) is a National Aeronautics and Space Administration graduate trainee.

G. W. PFEIFFER  
D. A. GURNETT  
S. D. SHAWHAN  
R. SHAW

Department of Physics and Astronomy,  
University of Iowa,  
Iowa City, Iowa.

<sup>1</sup> Gurnett, D. A., and O'Brien, B. J., *J. Geophys. Res.*, **69**, 1 (1964).

<sup>2</sup> Gallet, R. M., *Proc. Inst. Rad. Eng.*, **47**, 211 (1959).

<sup>3</sup> Smith, R. L., *J. Geophys. Res.*, **66**, 2578 (1961).

<sup>4</sup> Stix, T. H., *The Theory of Plasma Waves* (McGraw-Hill Book Co., Inc., New York, 1962).