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Study of nonlinear interaction of plasma wave using higher order spectrum in whistler frequency range

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Various types of wave phenomena in the whistler frequency range have been studied in the ionosphere-magnetosphere system in past, which specify the significance of wave-wave interactions in the space plasma. In our work we shall be paying attention on spectrum broadening processes which can be unified by the parametric (nonlinear) interaction of whistler mode waves with ionosphere and magnetospheres plasma [1]. These effects are enlightening on the basis of whistler wave interactions with small-scale plasma irregularities and quasi-electrostatic lower-hybrid resonance (LHR) waves. This process is analogous to the parametric interaction of high-frequency (HF) radio waves in the ionosphere F-layer near the reflection level [2].An analytical study of nonlinear-mode coupling between the VLF transmitter pulse and natural ELF/VLF emissions during the spectrum broadening by bicoherence analysis has been done by many researchers [3,4,5,6]. Therefore in this attempt we analyses the nonlinear wave-wave interaction in whistler frequency range by wavelet bicoherence analysis. In past the bicoherence analysis computed over the Fourier modes of the VLF signal but due to the non-stationary and non-Gaussian nature of VLF signal, we compute the bicoherence by a better tool termed as wavelet transform. The wavelet bicoherence mathematically define as [7]

$$[b^{w}(a_1,a_2)]^2 = \frac{|B^{w}(a_1,a_2)|^2}{[\int |W_f(a_1,\tau)W_f(a_2,\tau)|^2 d\tau][\int |W_f(a,\tau)|^2 d\tau]},$$

We have studied three events of spectrum broadening which are observed onboard DEMETER satellite. These signals are transmitted by the VLF transmitter FTU in LeBlance, France (46.37° N, 1.05°E) which is operating at18.3 kHz. With wavelet bicoherence it is found that the excitation of the lower hybrid (LH) waves (electrostatic waves) with the coherent waves from man-made VLF transmitter onboard DEMETER satellite is generated due to the nonlinear coupling. According to [8] the nonlinear scattering of VLF signals by ionospheric density fluctuations that solidifies the nonlinear mode alteration of VLF waves hooked on lower hybrid waves. These electrostatic modes consequence when the vaccinated VLF waves are scattered by ionospheric density instabilities with scale lengths less than$\sqrt{2}\pi(c/\omega_{pe})(\delta_e/\omega_o)^{1/2}$~2 in the upper ionosphere, where c, ω_{pe}, δ_e, and ω_o are the speed of light in vacuum, the plasma frequency, the electron cyclotron frequency, and the VLF wave frequency, respectively. The nonlinear scattering mechanism creates single-peaked spectra centered at the carrier frequency. Such types of spectra were witnessed during the experiments. Therefore, these cause mechanisms underwrite additively to the observed spectral broadening of introduced VLF waves.

1. Riggin, D., and M. C. Kelley, the possible production of lower hybrid parametric instabilities by VLF ground transmitters and by natural emissions, J. Geophys. Res., 87, 2545– 2548, 1982.
2. Gurevich, A. V., K. P. Zybin, and A. V. Lukyanov,Stationary striation developed in the ionospheric modification, Phys. Rev. Lett.,75(13), 2622–2625, 1995.
3. Tanaka Y., Lagoutte D., Hayakawa M., Lefeuvre F., Tajima S. Spectral broadening of VLF transmitter signals and sideband structure observed on Aureol-3 satellite at middle latitude.,J. Geophys. Res., V.92, p.7551, 1987.
4. Lagoutte, D., F. Lefeuvre, and J. Hanasz, Application of bicoherence analysis in study of wave interactions in space plasma, J. Geophys. Res., 94, 435– 442, 1989.
5. Sotnikov V.I., Fiala, V., Lefeuvre, F., Lagoutte, D. and Mogilevsky, M., Excitation of sidebands due to nonlinear coupling between a VLF transmitter signal and a natural ELF emission. Journal of Geophysical Research 96: 0148-0227, 1991.
6. Ohanmi S., M.Hayakava , T.F.Belland , T.Ondohwas ,Noninear wave- wave interaction in the subauroral ionosphere on the basis of ISIS-2 satellite observation of siple VLF signal,Geophysical Research Letter, Vol.20, No.8, pages 739-742, 1993.
7. MIlligen B.,E.Sanchez,T.Estrada,C.Hidalgo and B.Branas "Wavelet Bicoherence: A new turbulence analysis tool" physics plasmas 2(8), 3017, 1995.
8. Groves, K. M., M. C. Lee, and S. P. Kuo ,"Spectral broadening of VLF radio signals traversing the ionosphere", *J. Geophys. Res.*, 93(A12), 14683–14687, 1988 doi: 10.1029/JA093iA12p14683.