REMOTE SENSING LIGHTNING PARAMETERS FROM WHISTLER SPECTRUM

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Abstracts______Whistler originates from lightning over the earth. Its spectra contain much information about lightning parameters. We put forward a new method to sense remotely lightning parameters from whistler spectrum. The result by this method is in good agreement with experimental data.

I. INTRODUCTION

whistler is a dispersive electromagnetic wave propagating in space plasma. It originates from lightning over the earth. The acoustic frequency parts of lightning radiation propagate in space by two ways. One is the multi-reflection in the earth-ionosphere waveguide, propagating to remote distance. Another way is propagating approximately alone the geomagnetic field lines, from one hemisphere to another hemisphere with little absorption.(Zhou,et al,1988). By analysing the spectrum structure parameters of received whistlers, we may sense remotely the characteristic parameter of lightning sources.

II. WHISTLER SPECTRUM ANALYSIS

The system we use to analyse whistler spectrum consists of a Mini-Computer,and a Sonagram (Xiao,1987),see Fig.1.The bandwidth of sonagram is 0----32kHz. Fig.2 and Fig.3 are analysis results of one whistler. The whistlers analysed are from the Great Wall of China, the South Pole. Fig.3 represents the relation of intensity and frequency,standing for the same whistler as Fig.2. The peak frequency of this whistler spectrum is near f_{max} =3.1 kHz. Bandwidth Δf=2 kHz.

The bandwidth of VLF receivers used in China now, are generally in 0.8 kHz---16 kHz (Xu,1984). The VLF receivers respond linearly to electromagnetic waves in 1 kHz---7 kHz. The receiving system do not affect whistler spectrum.The dispersive, absorptive characteristics of ionospheric channel has some influences on whistler spectrum (Zhou and Sun,1988), but the influences can be neglected comparing with the influences of lightning sources and atmospheric wave-guide.

III. CALCULATION OF LIGHTNING PARAMETERS FROM WHISTLER SPECTRUM

The acoustic parts of lightning radiation are absorbed by atmospheric waveguide at places located far away from lightning souces (Machida,1984). It is very difficult to obtain information about lightning on the earth, whistler will play an important role in this aspect. Whistlers originate from lightning radiation of the conjugate point, they can propagate to places located far away from sourses with little absorption. The lightning which can produce whistlers, is generally cloud-earth lightning. The cloud-earth lightning radiation is approximately the diple radiation vertical to earth (Norider,1959). Whistler spectrum is determined by lightning spectrum.The return strokes of cloud-earth lightning can be considered as a discharge process of RLC series circuit (He,1981).The RLC circuits are formed by a capacitor of positive and negative charged body of thunderstorm and their mirror images, and by ionized channel of distribution parameters, as shown in Fig.4. After the ionized channel is formed, the charges on capacitor C will discharge alone this special channel.

This process can be described by the discharge equation of RLC series circuit. The lightning pulse voltage u_c:

$$u_c = \frac{V_0}{2}\left[\left(1 - j\frac{\delta}{\omega_0}\right)\cdot e^{-(\delta - j\omega_0)t} + \left(1 + j\frac{\delta}{\omega_0}\right)\cdot e^{-(\delta + j\omega_0)t}\right]$$

Where δ is attenuation ratio, ω_1 is the frequency of free oscillation; ω_0 is the carrier frequency

$$\delta = R/(2 \times L)$$
$$\omega_1^2 = 1/(L \times C)$$
$$\omega_0^2 = \omega_1^2 - \delta^2$$

This discharge process is attenuating oscillation, so the envelope of lightning pulse voltage u_c is a non-periodic wave packet. The spectrum of this wave packet can be obtained by Fourier Transformation:

$$|u(\omega)| = \frac{V_0\left[4(1+a_0^2)^2 + a^2(3+a^2-a_0^2)\right]^{1/2}}{\delta\left[(1-a^2+a_0^2)^2 + 4a^2\right]}$$

Where, $a = \omega/\delta$; $a_0 = \omega_0/\delta$

The peak frequency of this spectrum structure is a little larger than carrier frequency . If the difference of higher and lower frequencies of half amplitude of spectrum is defined as frequency bandwidth, the bandwidth is 3.6 when a =2.5. Considering the equations above concerning the relation of the spectrum parameters and distribution parameters R,L,C of ionized channel, we may find out the relation between the lightning parameters and the magnitude of spectrum parameters:

Peak frequency: $f_{max} = 0.93/(L \times C)^{1/2}$

Bandwidth : $\Delta f = 1.8 \times R/L$

f_{max} , Δf can be obtained from whistler spectrum, we may obtain two relations for lightning parameters like R,L,C. If one of R,L, or C is given,the other two values can be calculated.

From Fig.3, we know that, f_{max} =3.1 kHz; Δf=2 kHz. If typical measuring values of thunderstorm and lightning structure are adopted, the total potential of the center of negative charged body relative to the earth is approximately 2 10 V; the total charges of negative charged body is 30 Kulon, then

$$C = 0.84 \times Q/V = 12.06 \times 10^{-8} \quad (F)$$
$$L = 0.86/(f_{max}^2 \times C) = 18.4 \text{ (mH)}$$

The ionized channel is considered as a non-magnetized antenna of low frequency, and stand for the length and radius of ionized channel. We choose ρ = 5 cm (Leob,1964). The inductance of ionized channel is:

$$L = 4 \times \ell \times (\ln\frac{4\ell}{\rho} - 0.75) \times 10^{-7} \quad (H)$$

The length of ionized channel: ℓ = 3 km.
The heating resistance : $R = L \times \Delta f/1.8 = 129$ (Ω)
This infered values are in good agreement with observation results. From the spectrum analysis of a number of whistlers, we found that, the peak frequency and bandwidth of spectrum are variable, the peak frequency of spectrum changes from 1.8 kHz ---4 kHz, this means that the lighting parameters which determine the peak frequency are also variable.

IV. CONCLUSION

In this paper, a new method to sense remotely lightning parameters is put forward. The calculation from this method is in good agreement with experimental observation data. There remain some problems to be solved, for example, the ionospheric channel have some influences on the exact remote sensing of lightning parameters. We should take this influences into consideration in our further research.

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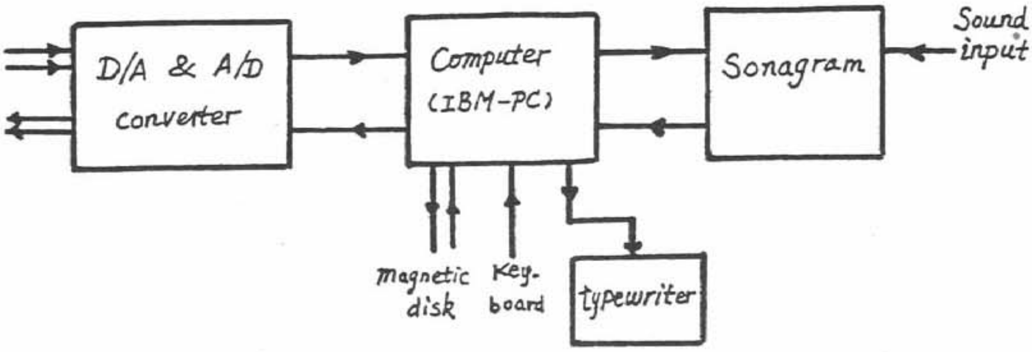

Fig.1 The illustration of whistler spectrum analysis system.

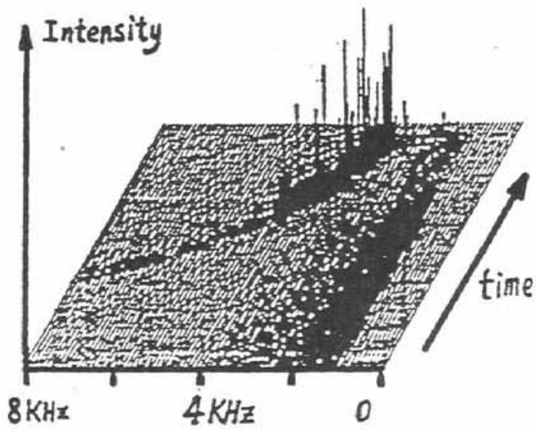

Fig.2 The 3-D whistler spectrum chart.

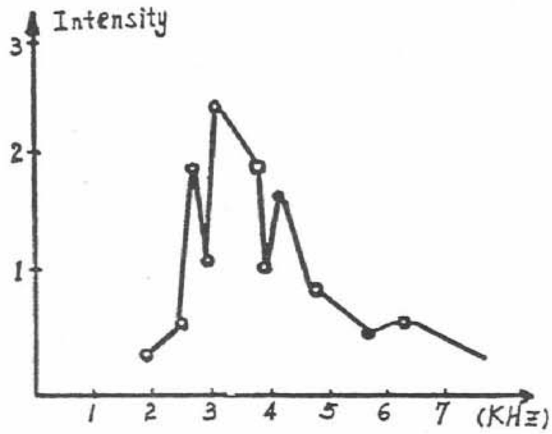

Fig.3 The 2-D spectrum chart from Fig.2.

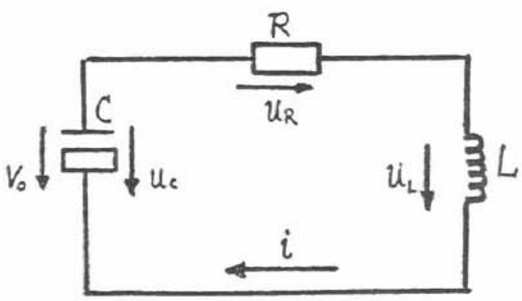

Fig.4 The RLC series circuit to simulate lightning discharge process.

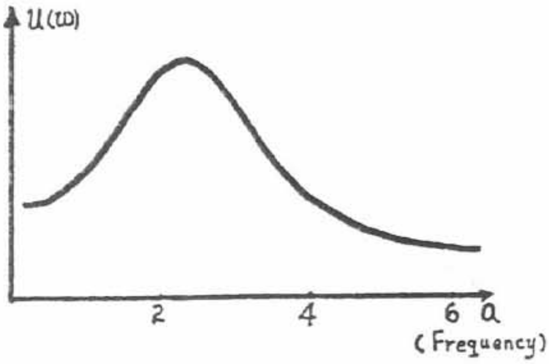

Fig.5 Amplitude spectrum of simulated lightning pulses.