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 propa-
gating 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 Δ f=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 atmos-
pheric 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:

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

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

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

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:

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

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 P = 5 cm (Leob,1964). The inductance of ionized channel is:

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

The length of ionized channel: ℓ = 3 km.
The heating resistance : $\quad R =L \times \Delta f/1.8 = 129$ (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.

REFERENCES

Croom, D.L.(1964), J.A.T.P. 26, pp1015
He you-wen(1981), J.Space Phys.(in Chinese), No.1, Vol.2, pp143.
Leob, L.B.(1964), J.G.R. 69,No.4
Machina, S. & Tsurnda, K.(1984), J.G.R. 89,A3, pp1675.
Norinder, H. & Knuden, E.(1959). Planet Space Sci.I,173-183.
Xiao Zuo,et al.(1987),J.Geophys.(in Chinese),Vol.30,No.6,pp653.
Xu J.S, Bao Z.T.(1983)J.Electr. (in Chinese),vol.12,No.4,pp110.
Zhou H.B. Xu J.S.and Hayakawa,M.,(1988). Planet Space Sci.
        Vol.36,No.8,pp833
Zhou H.B., Sun C.L.(1988). IEE: Sixth International Conference
        on Antenn.and Propag. Univ. of Warwick,U.K.April,1989.
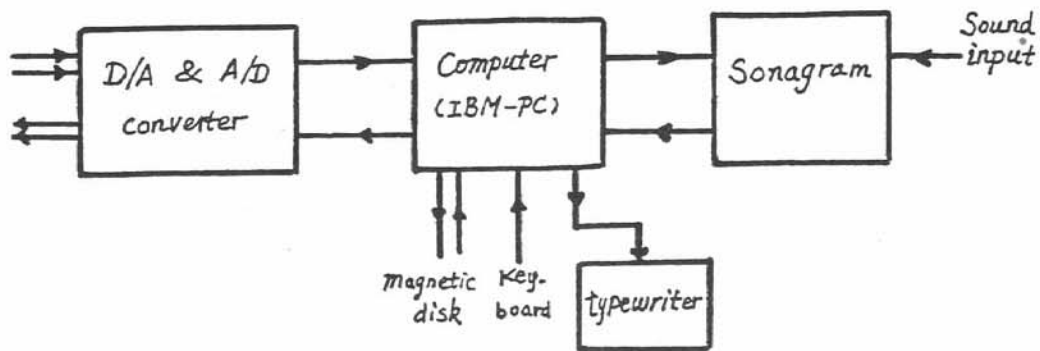
Fig.1 The illustration of whistler spectrum
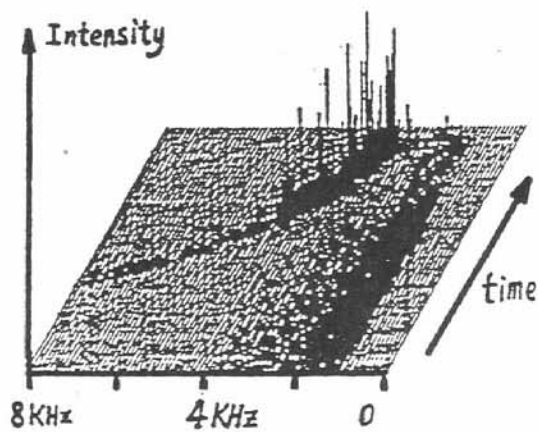analysis system.

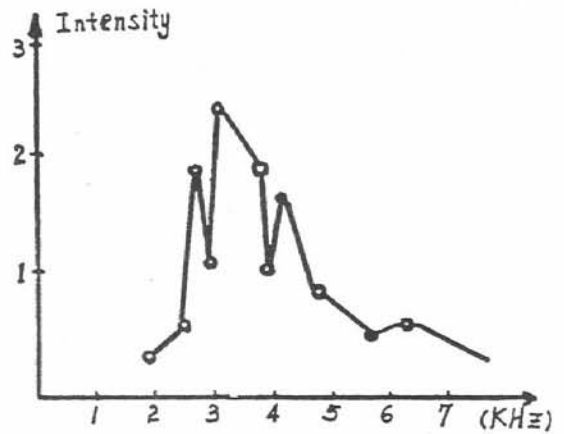Fig.2 The 3-D whistler
spectrum chart.
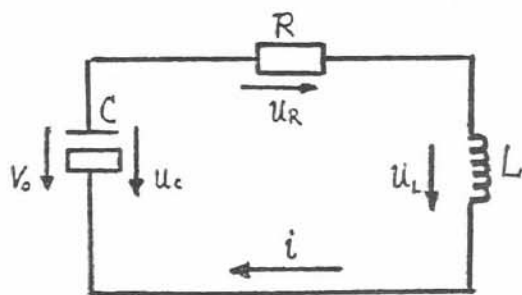

Fig.3 The 2-D spectrum
chart from Fig.2.
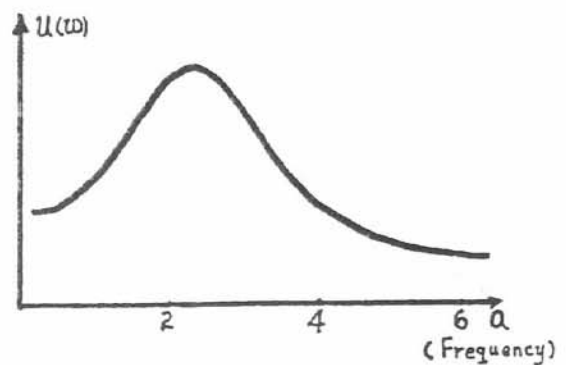

Fig.4 The RLC series circuit
to simulate lightning
discharge process.

Fig.5 Amplitude spectrum
of simulated lightning
pulses.