A New Method to Measure LF Time Code Service Signal Based on Virtual Instrument

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Abstract—**Both of the method and instrumentation for measurement of the low-frequency (LF) standard freuquency and time signal service system was proposed in the ITU-R new question draft published in Dec, 2005. Since the foundation of experimental LF time code service station (BPC) by National Time Service Center, Chinese Academy of Sciences in 1998, lots of research have been done in this field. Based on these research activities, a new generation of LF time code service station will run on May, 2007.**

The widely used method calculates field strength of the LF signal by the level of the received demodulation signal. To avoid the possibile measure error in the complicate environment, we should analyse the real measure environment.

In the paper, a new method is introduced to measure signal strength considering the characters of the LF time-code signal, which is based on the technology of virtual instrument. The induction signal on the antenna is amplified, filtered and sampled directly. Then, the discrete signal is analyzed and calculated by digital signal processing and adaptive trap filter which restrain the narrow-band interference.

We have designed and developed a portable, stable and extendable measure instrument, in which the field strength, the carrier phase and the signal wave is available. It has been used in our practical measurements. The results show that the diffenece of the field strength measured by Anritsu ML428B and our instrument is less than 1 dBμv / m . The carrier phase time resolution reaches 1 μs .

I. INTRODUCTION

Low-frequency time-code time service is a technology that is encouraged by ITU-R, the low-frequency radio wave band in low- frequency time code timing system can be used to transfer standard time frequency in large area as following features: stable transmission、widely effective coverage、strong penetration capability and can react with ionosphere [1]. The low-frequency time code service station (calling code BPC) was founded by national time service center, Chinese Academy of Sciences. The signal of low-frequency time code is showed in figure1, amplitude modulation and pulse width modulation are both used in BPC, the carrier wave frequency is 68.5 kHz, and information rate is 1bit /s, the amplitude of carrier frequency will decrease to 25% of original amptitude when the time of each second coming, different width of the falling pulse indicates different time information.

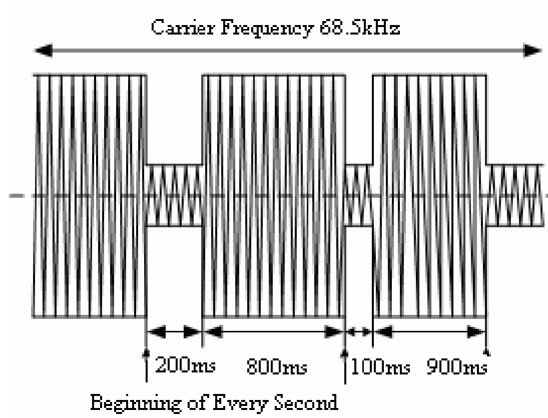

Fig.1. Low- frequency time code signal sketch map

Field strength and carrier phase are two importance parameters in the quality of low-frequency time code signal transmission. Field strength reflects signal coverage, and the stability of the carrier is related with the timing accuracy of low- frequency time code timing closely. The measurement will be impacted by complex electromagnetic environment when measuring the two parameters. It is found that terrain、climate 、 the height of receiving antenna 、 trees and atmospheric environment etc would strongly impacted the result of field strength measurement. In the experiments, the value of field strength measurement would be different with several dBμv / m when we measured at the same point with different environment, the impact of the measurement environment will be described in another article for the limitation of this paper. ITU-R has made a point of the measurement of low-frequency time code signal. In December of 2005, ITU pointed out in 7/6 draft [2], for the interference during SFTS between 20 and 90 KHz, the method and standard instrument to measure signal strength is still not available now, or this kind of method and instrument is still rare, and the research for the measurement method、measurement instrument and interference of low-frequency time code has been placed into new research problems. In this paper, we will introduce the theoretical background of low-frequency time code measurement. Details of the measurement method for low- frequency time code signal base on virtual instrument technology is presented in section 3. The system of low- frequency time code signal measurement is described in section 4. Finally, the result of some Typical measurement is given.

II. THE MEASURING PRINCIPLE

The frequency between 20~90 kHz is called low-frequency radio waves. Usually, we think that these radio waves are regarded as transferring with different modes between ground and lower ionosphere. The magnetic antenna were used during measuring, according to the principle of wave and antenna, we know that, when the antenna has the same direction with the polarized direction of measured signal in the aerosphere, the antenna would get the maximum induction signal. Assumed AF is the gain of antenna, indicated by dBi normally. At one measuring point, the relations between the field strength value of measured signal and the received signal level (RSL) is:

$$E_S = RSL - AF - 20\lg L_e \quad (1)$$

Where L_e is the effective length of receiving antenna.

In the actual measurement of low frequency signal, for the amplification coefficient of the amplifier A_m and feeder and other loss L_f, above equation can be changed to:

$$E_S = RSL - AF - 20\lg L_e - A_m + L_f \quad (2)$$

From above equation we can know, the measurement for filed strength is equal to the measurement of the induction signal on the antenna. For the reason of low carrier frequency in low-frequency time code signal, the induction signal can be converted to digtal signal and processed instead of anglog detector. As a result of digtal signal processing, the impaction of inteference in the measurement is decreased to minmum. The detail measuring method: first, the received low-frequency received on antenna is amplified and wide band filtered, then converted to digtal signal by A/D , after that, the sampled signal is filtered by digtal filter, then the amplitude of the signal is calculated. In the signal processing procedure, adaptive trap filter is used to impress the severe narrow-band inteference for best measurments.

Comparing the signal wave of low-frequency time-code signal in figure1, at the time of each second, the carrier amplitude would fall to 25% of the original amplitude. To measure the filed strength and carrier phase of signal correctly, to avoid the decline of carrier amptitude, and the phase measurement of this stage would be impacted by the interruption easily, therefore, we take the signal of GPS pulse per second (1pps) as reference point of filed strength and phase measurement. The measurement of signal would be accurate when delaying GPS 1pps signal to the time of carrier amplitude recovering to original size.

III. LOW-FREQUENCY TIME-CODE SIGNAL MEASURING SYSTEM

A. *System Structure*

Low-frequency time code signal measuring system (LFMS) based on the virtual instrument technology uses software development kits of US NI Company—LabVIEW. The concept of virtual instrument technology is using the software to perform data analyze and display, it is a computer instrument system that completing the thinking of “ software is instrument “ really. The customer can design and define the system base on technical requirement and functional form, the measuring function can be implemented by computer software, and the display function can be indicated by the virtual panel of computer monitor, all the three functions are executed on the hardware platforms of common micro-computer with standard communicated connector [3,4].

LFMS measures the field strength of low-frequency signal transmitted by BPC sevice station, takes carrier phase, recovery signal and carrier waves, sets up database, at the same time, it would display the variation of receiving signals in time. The system includes four parts: antenna parts、receiving processing parts、signal processing parts、controlling display parts. Among the four parts, receiving processing parts includes radio frequency channel module、reference signal module、frequency standard benchmarks and power module . Basic system structure is shown in figure 2.

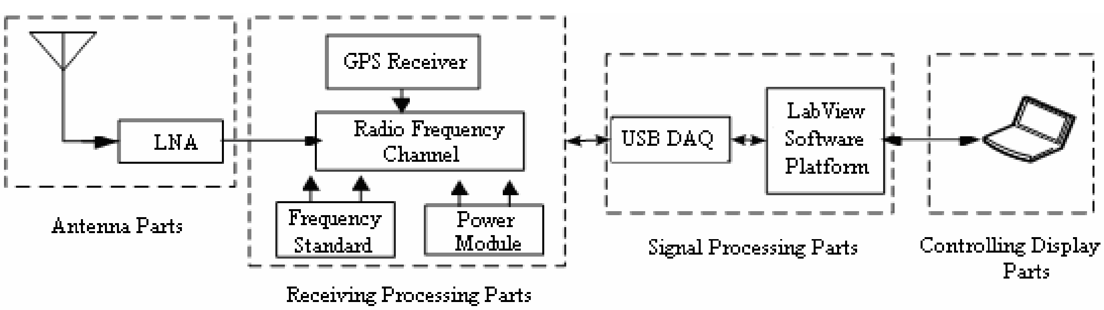

Fig.2. Low-frequency time code signal measuring system structure

B. Signal Measurement Process

LabVIEW is based on the data-flow software, the figure given the low-frequency time code signal measurement system data flow process.

First a data sampling of 1pps delay triggering with GPS was conducted, then digital filtration was made to the sample signals, and the timely screening of the signals were given. After that, measurement of the peak data is made, after getting the peak, the threshold was calculated. In accordance with the different formula, a proper threshold was chosen, and the ineffective data were deleted, then the peak data were made average so as to reach RSL. According to the antenna factors and the feeder loss, the field strength was calculated, and at the same time the wave carrying phase were measured, the results were timely displayed, and the date and time were marked for later consultation. Repeated averaging can reduce the interference of white noise to the data, and the deletion of bigger data can help to avoid the sudden pulse interference.

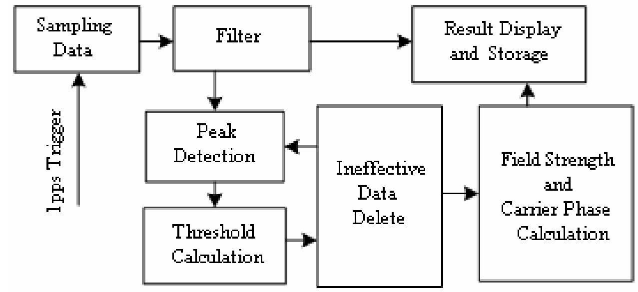

Fig.3. Low-frequency time code signal measurement flow

IV. RESULT ANALYSIS

A. Actual Waves

The judgment of the surveying environment is the key to the measurement of LFMS, and its changes directly affect the results. In actual survey, in order to have a clear idea about the surveying environment, we had a timely screening of the signals' waves, and marked their spectrum. The following chart shows the actual waves and their spectrum within a ground wave range. As is shown in the figure 4 and figure 5, this system vividly displays the waves of the measured signals. From the analysis of spectrum, we can see that the surveying environment of this spot is satisfactory, and the result is reliable. The longitudinal coordinates shows the enlargement degree of the sample signals, and the abscissa indicates time.

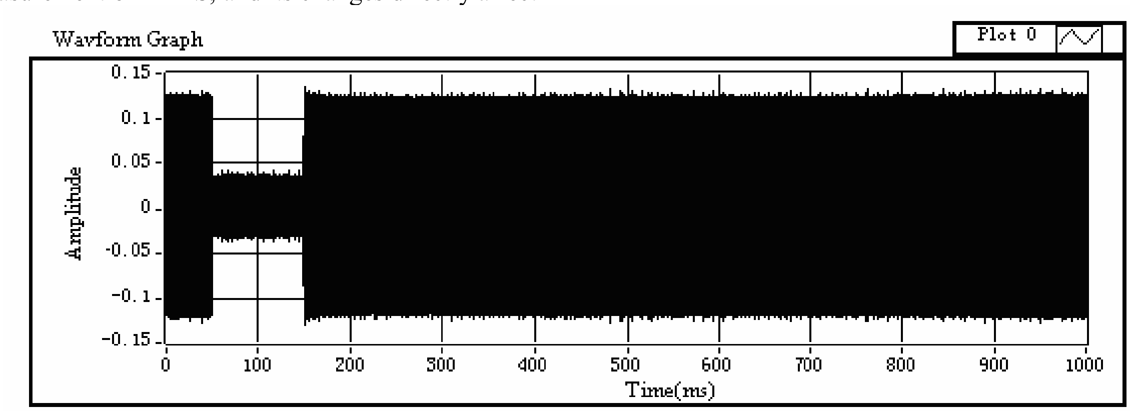

Fig.4. Actual waves of low frequency time code signal

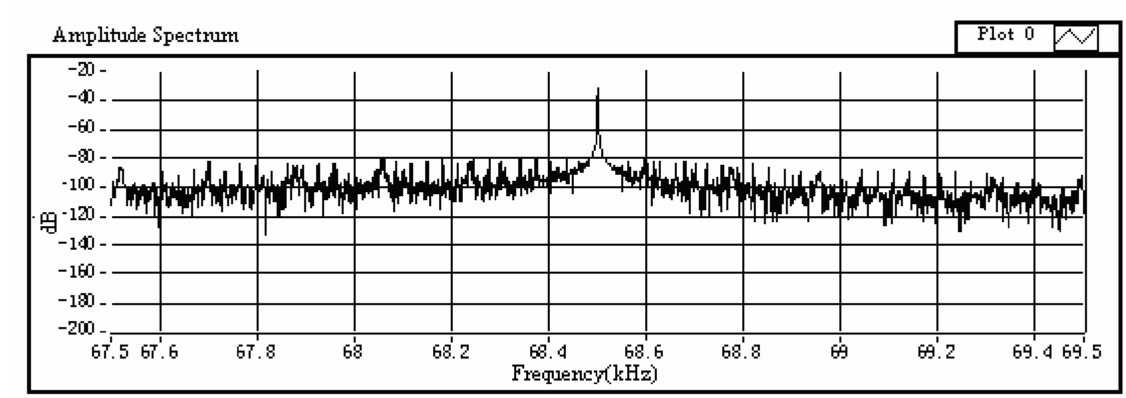

Fig .5. Spectrum of the low frequency time code signal

B. Field Strength Measurement Comparisons

In December 2006, we made a comparative experiment between the LFMS and the ML428B, which was mainly about the measurement of the field strength of signals. The comparative experiment was conducted not only on the measurement result with the launcher in full power, but also on various instruments' measurement data and their linear changes with the launcher in different powers. With regard to the unique features of the launchers of the low frequency time code pad, in the experiment, we divided the launching power into 4: namely full power, two-thirds power, one- third power and one-sixth power. The experiment site was 70km away from the launching pad, which enjoyed a favorable environment of measurement. The comparisons of the results are shown in the chart below, from which we can conclude that ML428B and LFMS are approximately the same in the measurement data of field strength, with the difference of less than 1dB.

TABLE I. COMPARISON RESULT（UNIT： dBμv / m ）

	Full Power	Two-thirds power	One-third power	One-sixth power	Recover full power
ML428B	85.1	82.07	76.03	69.70	84.58
LFMS	84.7	81.74	76.11	70.06	84.6
Error	-0.4	-0.33	0.08	0.36	0.02

C. Analysis to the Carrier Phase Measurement

Every time when the GPS second pulse delay is triggered, the low-frequency time code signal measurement system begins to measure the carrier phase, and detect the zero point in the sampled singal. With a △t illustrated in figure 6, we can get the following carrier phase:

$$\text{phase} = T - \Gamma - N \times \frac{1}{f} + \Delta t \qquad (3)$$

Here, $\Delta t = \tau n$, T refers to GPS second signal delay, Γ refers to electric wave spread delay, f is carrier frequency, N is the carrier number within the T intervals, τ is the sampling cycle of signals, and n is the number of sample signal when the zero point is detected.

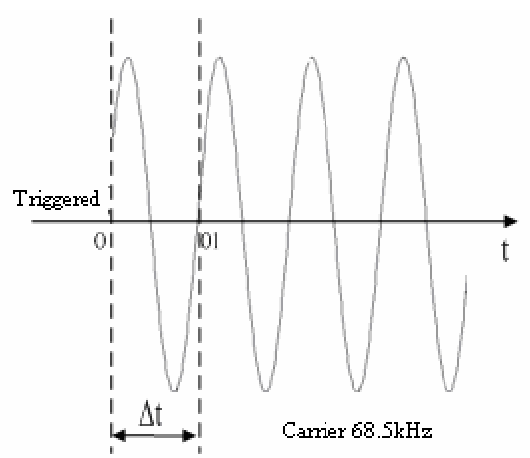

Fig.6. Phase measurement diagram

The time resolution of carrier phase is related to sampling frequency, the stability of GPS second signals and the interference of signals. The output stability of GPS second signals is 0.1us. Generally speaking, the higher the sampling digits and the frequency, the higher the resolution. For the low-frequency carrier signal, we use a sampling rate of 1.25M, and the time resolution of carrier phase is 0.8us. From 9:00 to 12:30 on November 27th 2006, we conducted carrier phase measurement of low-frequency time code signal, which is illustrated in figure 7. As is shown in this figure, low-frequency time code signal have constant phase changes at certain period of time, which proves to be affected by the launching pad. The measurement indicates that carrier phase of low-frequency time code signal are stable. And the standard variety is 0.27μs

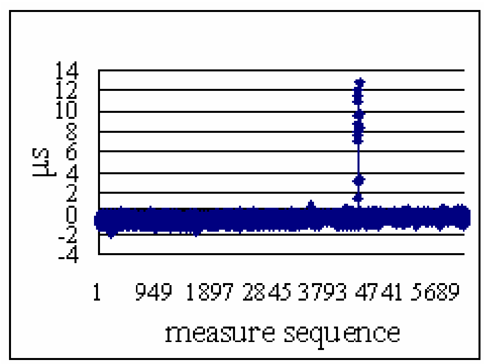

Fig.7. Phase difference measurement data

V. CONCLUSION

This paper introduces a measuring method of low-frequency time code signal based on virtual instrument technology. This low-frequency time code signal measurement system has the advantage of stability, portability, and simple operation, which especially adapted well to field measurement, and can basically meet the requirement of low-frequency time code signal measurement with its present functions. LFMS still has much room for expansion. Its actual application can be further optimized, so that it becomes simpler and more reliable.

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