International Journal of u- and e- Service, Science and Technology
Vol.9, No. 9 (2016), pp.407-418
http://dx.doi.org/10.14257/ijunesst.2016.9.9.37

A Method for The Evaluating Performance of High Power Electromagnetic Transmitter

Xiguo Ren[1], Yiming Zhang[1], Haijun Tao[1,2] and Xuezheng Zhu[1]

[1]*Beijing University of Technology, Beijing 100124 China*
[2]*Henan Polytechnic University, Jiaozuo 454003 China*
xiaoxifree@126.com

Abstract

In recent years, the Earth's resources have the obvious contradiction between supply and demand. Electromagnetic has become the most effective means for prospecting geological structure. In the electromagnetic method, the transmission frequency has a significant impact on the reception and subsequent analysis. Therefore, the distribution and stability of the actual transmission frequency is an extremely important factor in judging for the transmitter. This paper presents an assessment method of the transmitting the performance parameters for the high-power electromagnetic transmitter. This method can intuitively observe the actual transmission frequency by the position machine when the transmitter is working. And the frequency distribution and stability could be got by Matlab. After a large number of comparative field trials, this method is verified which could quickly and efficiently get the frequency distribution and stability of the actual transmitting. This method could provide a basis for future inversion calculation and have a guiding role for the transmitter optimization.

Keywords*: Electromagnetic; the transmission frequency; high-power electromagnetic transmitter; the distribution and stability; field trials*

1. Introduction

In recent years, oil and gas resources are more supply and demand contradiction. 78% oil and 93% of natural gas has not been discovered in the prospective resources. However, because of the complexity of the geological conditions, that exploration is difficult, especially in the depth exploration[1]. Electromagnetic method can fetch the response of electromagnetic field through the medium of the earth, which will get the information of the orebody conductivity and its structure [2]. Therefore, the electromagnetic is the most effective means of detecting the geological structure in the geophysics.

From the 1980s, the Phoenix of Canada has launched a series of electromagnetic transmitters, like V4, V6 and V8 [3-5].The maximum power of V8 transmitter can reach 20kW, its current from 0.5A to 40A.And the Zone of US also launched the GDP12, GDP16 and GDP32 electromagnetic transmitter [6-7], the power range from 3KW to 30KW, the output voltage from 50V to 1000V.China has studied the equipment of the electromagnetic from the early 1970s [8-10].Though the transmitter of our country played an important role in the shallow metal ore exploration, using electromagnetic transmitter couldn't prospect the structure and metal ore in the deep earth for power, precision, stability of the transmitter. In recent years, the team of Professor Zhang Yiming reaches the SEP transmitter by the deep exploration techniques and experimental study [11]. Mainly for research high-voltage power transmitter technology is in electromagnetic detection system .It provides theoretical support and technical support for China's high-power electromagnetic transmitter in the electromagnetic exploration. But no matter the Phoenix company's production V8 electromagnetic transmitter, Zonge company launched GDP32 electromagnetic transmitter, or our national self-developed high-power

ISSN: 2005-4246 IJUNESST

electromagnetic transmitters SEP doesn't have a more robust evaluation for the high-power electromagnetic transmitter. Since the transmitting frequency has a major role in electromagnetic method [12], the stability and distribution of the actual transmission frequency is an extremely important factor for the transmission effect. This paper presents an assessment method of transmitting performance parameters for high-power electromagnetic transmitter. This method can be observed visually to the actual transmitting frequency when the transmitter is working. The distribution and stability of the actually transmitting frequency can be getting by computer processing. It provides a frame of reference for the receiver receiving the data, calculating the apparent resistivity, the plant division and depth. And it also could optimize for the high-power electromagnetic transmitter.

2. Effect of Frequency in Electromagnetic Method

According to the formula of the source in the electric and magnetic field on the ground:

$$E_x = \frac{I \bullet AB \bullet \rho_1}{2\pi r^3}\left[e^{ik_1 r}\left(1-k_1 r\right)+\left(3\cos^2\theta-2\right)\right] \tag{1}$$

$$\begin{aligned} H_y &= \frac{I \bullet AB}{2\pi r^2} \bullet I_1\left(-\frac{ik_1 r}{2}\right) \bullet K_1\left(-\frac{ik_1 r}{2}\right)\left(1-4\sin^2\theta\right) \\ &+ \frac{iIAB}{8\pi r}\sqrt{\frac{i\mu_0\omega}{\rho_1}} \bullet \left\{\left(\cos 2\theta - 1\right)\left[I_0\left(-\frac{ik_1 r}{2}\right) \bullet K_1\left(-\frac{ik_1 r}{2}\right) - I_1\left(-\frac{ik_1 r}{2}\right) \bullet K_0\left(-\frac{ik_1 r}{2}\right)\right]\right\} \end{aligned} \tag{2}$$

I is the current of transmitter, AB is the distance of transmitter emitter, k_1 is wave constant, I_1, I_0, K_1, K_0 is Bessel function of imaginary argument.

$$\rho_s = 0.2\mathrm{T}\left|\frac{E_x}{H_y}\right|^2 = \frac{1}{5f}\left|\frac{E_x}{H_y}\right|^2 \tag{3}$$

The frequency (f) and the apparent resistivity (ρ_s) is closely related from the formula (1), (2), (3).And the apparent resistivity (ρ_s) is parallel movement with the frequency (f) increasing from the curve of apparent resistivity and frequency.

From the formula

$$H_y \approx \frac{1}{r^3\sqrt{\sigma_1 f}} \tag{4}$$

And

$$\frac{E_x}{H_y} = \left[\frac{1}{\sigma_1 r^3}\right] \Big/ \frac{1}{r^3\sqrt{\sigma_1 f}} = \sqrt{\frac{f}{\sigma_1}} = \sqrt{\rho_1 f} \tag{5}$$

From the formula (4), (5), the frequency f for dividing the plant also has an important significance.

$$h_{effective} = \frac{\lambda_1}{2\pi} = \frac{\sqrt{\frac{10^7\rho_1}{f}}}{2\pi} = 503.3\sqrt{\rho_1 / f} \tag{6}$$

Operating frequency is related with the probing depth too in the formula (6).

From the above analysis, the frequency f plays an extremely important role in the apparent resistivity (ρ_s), the structure of the ground, the division of geomagnetic

factory and the probing depth. The calculation and inversion of these data will have a crucial influence if the frequency is not stable.

Therefore, the distribution and accuracy of the actual transmission frequency are the extremely important factors to determine the effect of the transmitter. This paper presents a novel approach to evaluate the performance parameters of the transmitter.

3. Evaluation Method

The real-time sampling circuit is used for the output voltage, output current, and the actual transmission frequencies. The result is given the position machine. The transmitter could be got the actual effect by the processing data from the position machine. The flow chart is shown in Figure 1.

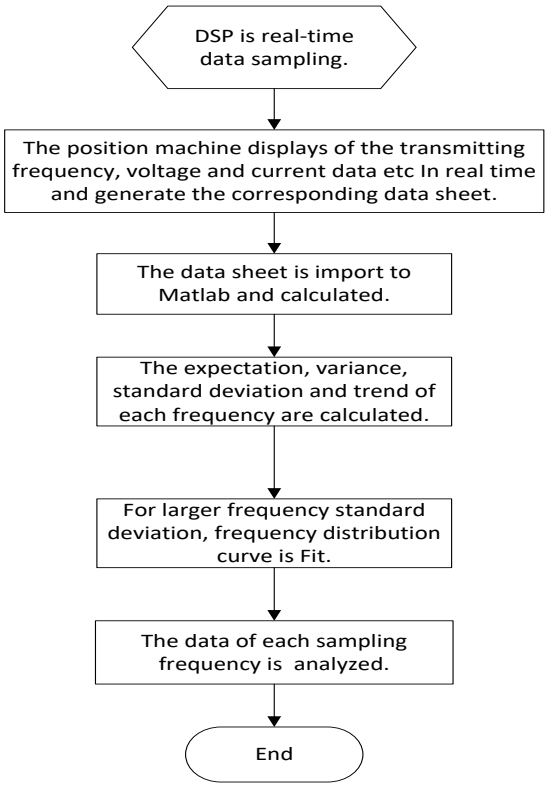

Figure 1. The Flow Chart of Transmitter Data Sampling and Processing

The approach would be introduced when the transmitter works at 7680Hz.

Firstly, the output voltage, output current and frequencies are real-time sampling. The data signal is sent to the position machine after the DSP system is initial processing as shown in Figure 2.

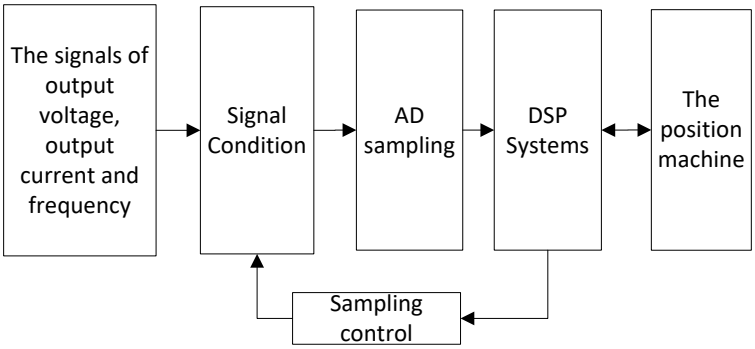

Figure 2. Multi-Channel Data Acquisition and Analysis System by DSP

These data could be real-time displayed on the position machine and stored in an Excel table like Figure 3.

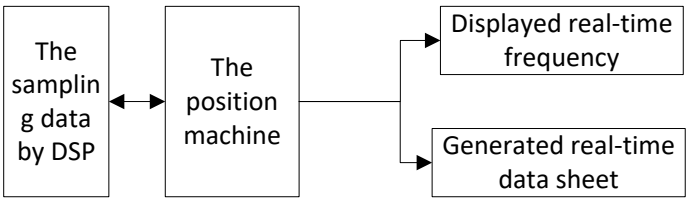

Figure 3. The Function of Position Machine

Figure 4, is a display interface while the transmitter is working at 7680Hz. The display interface could display transmission voltage, transmission current and actual frequency. These data would be recorded and stored in an Excel data table.

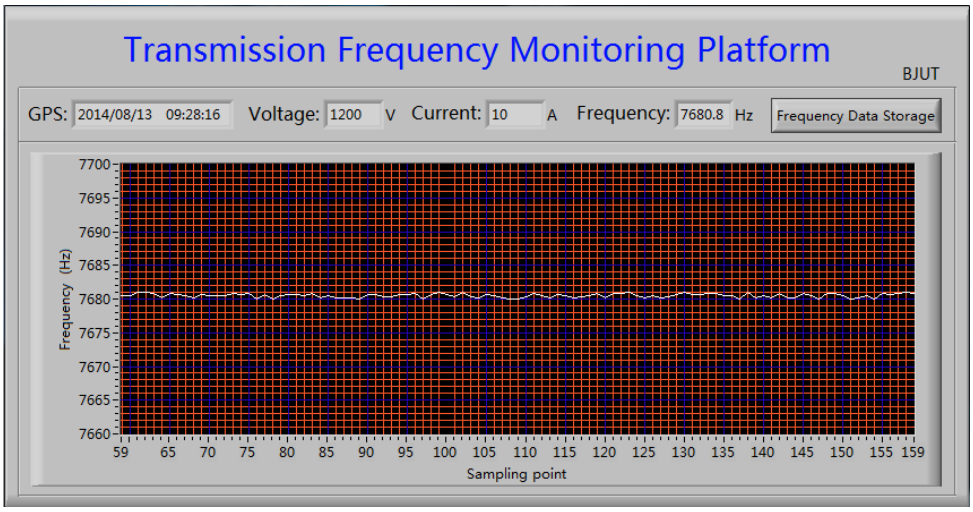

Figure 4. The Display Storage Interface of the Position Machine

From the figure, the frequency of the transmitter and its distribution could be clearly shown in the position machine

The output voltage, output current, and the actual frequency would be saved in an excel table by the position machine. The following table from left to right recorded the value of peak to peak voltage, frequency and the value of peak to peak current, and the number of leftmost column is the cycle number.

Table 1. Some Data of the Sampling Sata at 7680Hz

	A	B	C	D
1	Xviewer			
2		CH1 P-P	CH1 Freq	CH3 P-P
3		V	Hz	A
4				
5	block0			
6	max	898.67	7681.10	7.60
7	min	872.00	7678.70	7.30
8	ave	886.85	7680.00	7.40
9	sdev	3.0045	0.36951	0.032979
10	count	15375	15375	15375
11				
12	0	890.67	7679.9	7.4
13	1	886.67	7679.9	7.4167
14	2	892	7679.3	7.4167
15	3	886.67	7680.5	7.4
16	4	885.33	7679.9	7.4
17	5	886.67	7680.5	7.4
18	6	886.67	7679.9	7.4167
19	7	890.67	7679.3	7.3333
20	8	882.67	7679.9	7.4
21	9	882.67	7679.9	7.4
22	10	888	7680.5	7.4167
23	11	882.67	7679.9	7.3833
24	12	886.67	7680.5	7.4
25	13	886.67	7679.9	7.4
26	14	892	7679.9	7.3667

7680Hz

Finally, using the MATLAB export the data from the table [13]. And the expectation, standard deviation and distribution trends are calculated by it.

The calculation process is as follows:

Assuming that the number of sampled frequency is n at each frequency point, respectively, x_1, x_2, ... x_n ,it is expressed as the formula (7)

$$\bar{x} = E(x) = \frac{x_1 + x_2 + \ldots + x_n}{n} \tag{7}$$

The variance is used to measure the deviation of the random variable and its mathematical expectation, its mathematical expression is such as formula (8)

$$\overline{D(X)} = s^2 = \frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \cdots + (x_n - \bar{x})^2}{\mathrm{n}} \tag{8}$$

When $\overline{D(X)}$ is used as the variance of the sample X, its mathematical expectation is not the variance for X, but the (n-1) / n times of the variance. The mathematical expectation of D(X) is the variance for X, the more accurate formula of variance is

$$D(X) = s^2 = \frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + ... + (x_n - \bar{x})^2}{n-1} \tag{9}$$

Used $D(X)$ as an estimate of the variance for X has "Unbiasedness". So $\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + ... + (x_n - \bar{x})^2}{n-1}$ is always used to estimate the variance for X. In the same sample size, the greater of the variance is meaning the greater fluctuations in the data, the more unstable.

After the variance, the standard deviation is obtained as formula (10) below:

$$\sigma X = \sqrt{D(\mathrm{X})} \tag{10}$$

Also the greater standard deviation is described that the larger volatility in the data, the more unstable for the frequency.

For the set frequency, actual frequency is respectively expressed a_1, a_2 ...a_n. The number of the corresponding frequency is representing b_1, b2…b_n. And its probability is shown c_1, c2…c_n. The probability of actual frequency at the set frequency is shown by the formula (11)

$$c_n = \frac{b_n}{\sum_1^n b_k} (n = 1, 2, \ldots m) \tag{11}$$

c_n represents the probability of each actual frequency, b_n represents the number of the corresponding frequency, b_k represents the number of the each actual frequency.

According to the calculated standard deviation, the distribution curve of standard deviation is drawn. The transmission stability for the transmitter can be obtained by the curve. The standard deviation is larger, its actual frequency is more volatile, and the impact of subsequent analysis is more serious.

For the standard deviation larger setting transmission frequency, the distribution of the actual frequency at the set frequency is curve fitting using the least squares method in this paper. The probability distribution curve of the actual frequency would be got. The difference between the upper and lower limits of the actual frequency is smaller; the probability of the set frequency is greater, and the effect of the transmitter is better.

4. Field Experiments and Verification

4.1. The Contrast Between the V8 Transmitter and SEP1 Transmitter

From March to September in 2013, the group own research SEP1 transmitter and V8 transmitter respectively went to Gansu, Liaoning, Inner Mongolia and other places for field comparing experiments. Using the above method to test, the results would be shown as follow.

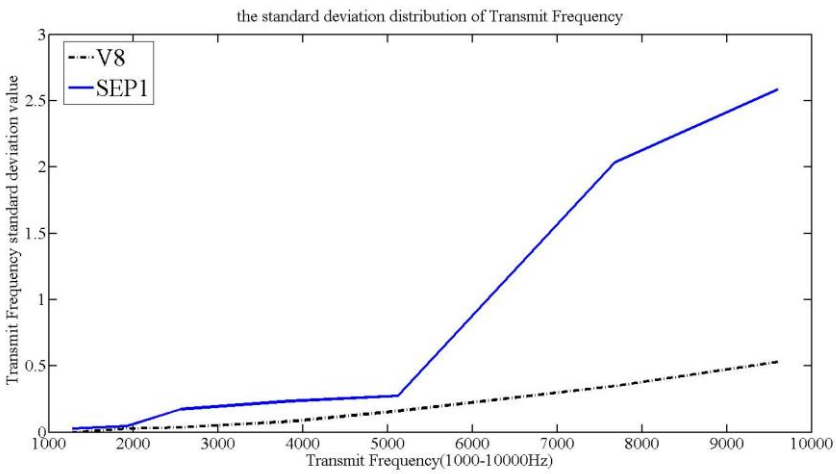

Figure 5. The Standard Deviation Distribution of the Transmission Frequency for V8 and SEP 1 Electromagnetic Transmitter

From the chart 5, the standard deviation is small (less than 0.01) between V8 and SEP1 when they worked at the low frequency. At the high frequency stage (3000Hz above), the standard deviation of the V8 transmitter is close to 0.6, while the standard deviation of SEP1 transmitter is exceeds 2.5. So it is proof that the standard deviation of the transmitters is relatively large at high frequency, and the stability of V8 transmitter is better than SEP1.

The distribution of the actual transmitting frequency between the V8 transmitter and SEP transmitter is reveal in the Figure 6-8，when they worked at in the high frequency stage.

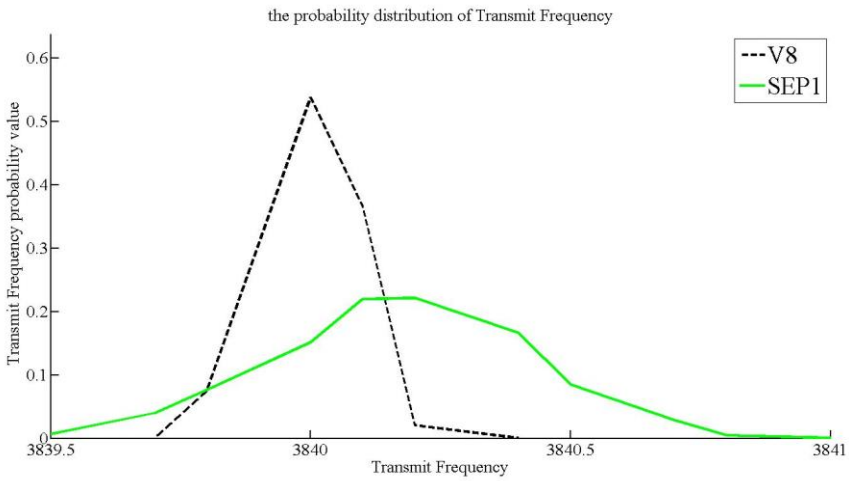

Figure 6. The Actual Transmission Frequency Distribution Between the V8 and SEP Transmitter at 3840Hz

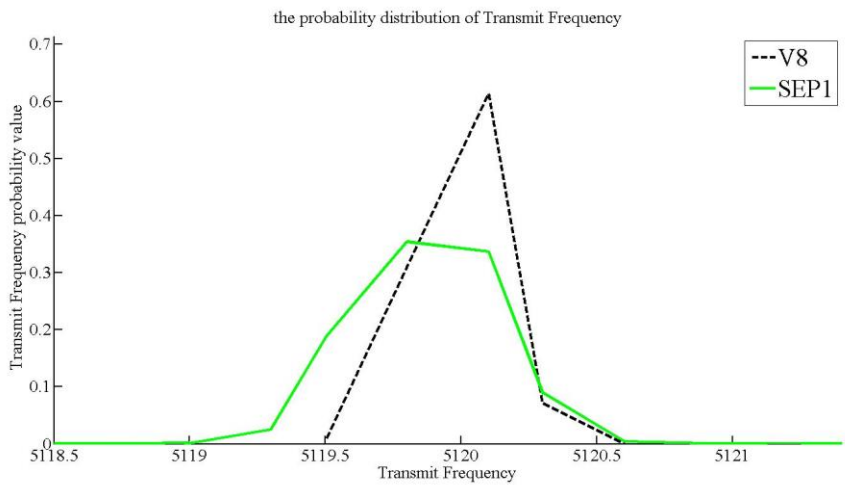

Figure 7. The Actual Transmission Frequency Distribution Between the V8 Transmitter and SEP Transmitter at 5120Hz

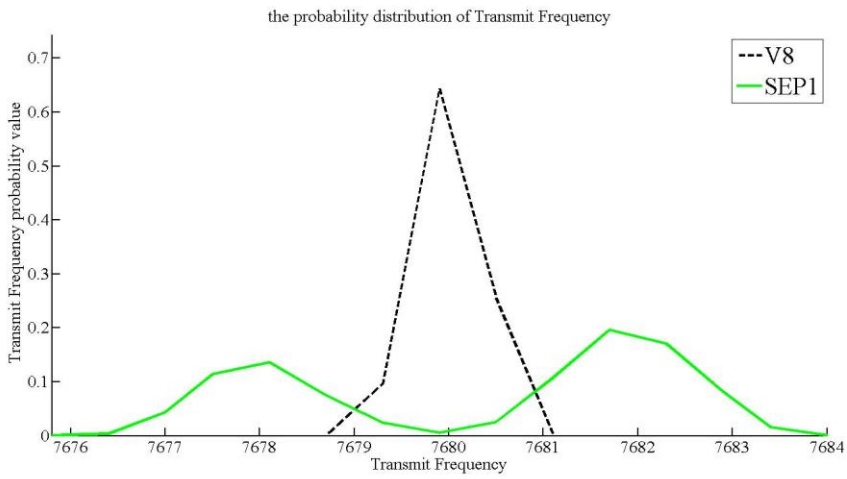

Figure 8. The Actual Transmission Frequency Distribution Between the V8 Transmitter and SEP Transmitter at 7680Hz

As it can be seen from Figure 6-8, either the V8 or SEP1 works at the higher frequency, its actual transmission frequency has a range fluctuation. And the V8 transmitter deviation is less than SEP1. V8 transmitter could be very accurate and stable at the setting frequency but SEP1 not. Transmission effect can be clearly seen from the probability distribution, the distribution of different transmitters in the same frequency and the actual transmission frequency of the upper and lower limits can be seen at a glance. The actual difference between the upper and lower limits is smaller; the probability of set frequency is greater, the transmitter transmission effect is better.

Because when the frequency is less than 3000Hz, the standard deviation of the transmitters is relatively small, the actual transmission frequency almost does not change at this time. So here is not to draw the distribution at these frequencies. Based on these graph, it can be get distribute of the actual transmission frequency, which could be clearly seen the transmitter transmission effect and provides the basis for the receiver data analysis later.

By this method, it can be found that the standard deviation of V8 transmitter changes smaller at the high frequency, but it is large for SEP1. Therefore, the further improvements should be need in the control mode and the hardware circuit.

4.2. The Contrast Between the V8, SEP1 Transmitter and SEP2 Transmitter

After technical improvements, group manufactures SEP2 transmitter and conduct field experiments to these areas. The test results of the transmitters are obtained after repeated experiments.

Compared SEP2, V8 and SEP1 transmitter transmitting, the actual standard deviation distribution of the transmit frequency has been got as the Figure 9.

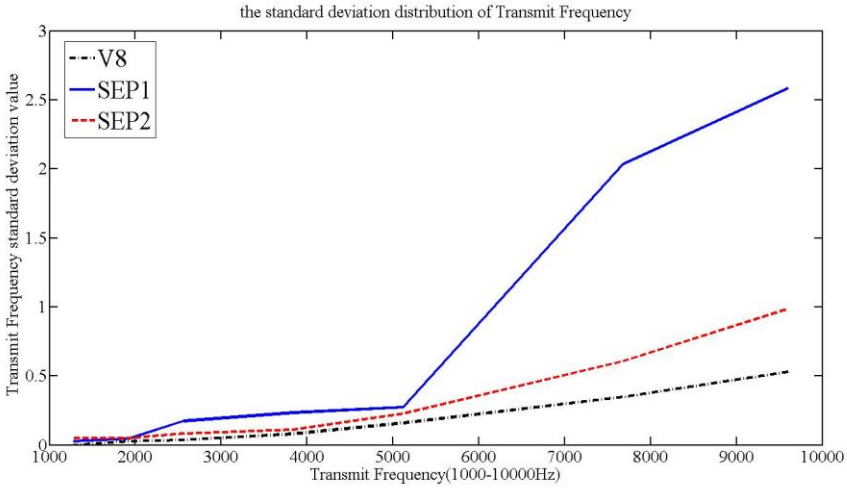

Figure 9. The Standard Deviation of the Actual Transmission Frequency between the V8, SEP1 and SEP2 Transmitter

From Figure 9, standard deviation of the SEP2 transmitter has been far less than the SEP1, but it is still a gap with the V8. Its stability is better than SEP1 transmitter, performance has been greatly improved.

The actual frequency distribution curve of three transmitters is obtained by fitting at the high frequency stage shown in Figure 10-12.

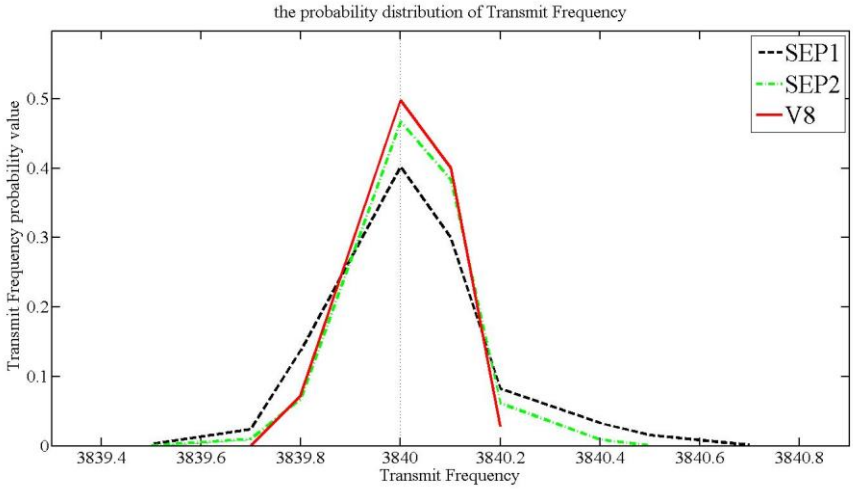

Figure 10. The Actual Transmission Frequency Distribution Between the V8, SEP1 and SEP2 Transmitter at 3840Hz

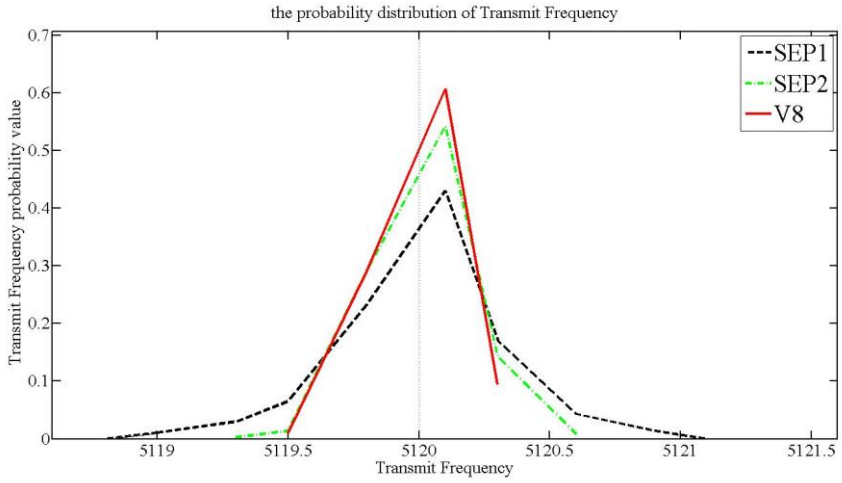

Figure 11. The Actual Transmission Frequency Distribution Between the V8, SEP1 and SEP2 Transmitter at 5120Hz

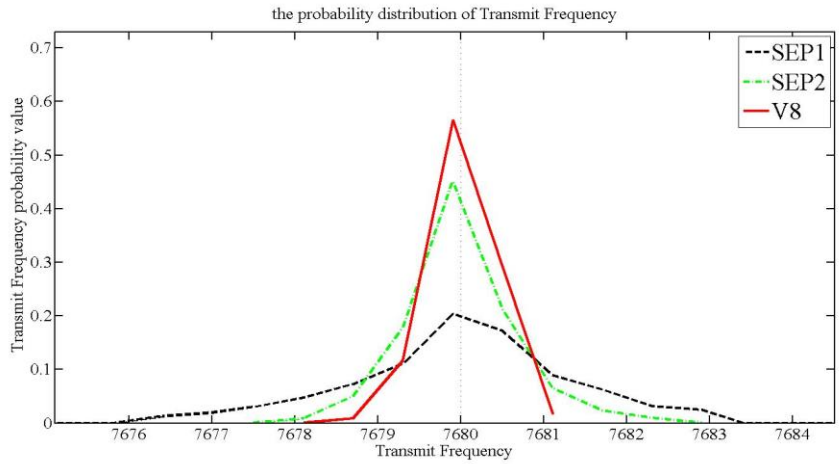

Figure 12 The Actual Transmission Frequency Distribution Between the V8, SEP1 and SEP2 Transmitter at 7680Hz

From Figure 10-12, at the high frequency stage the actual frequency distribution of SEP2 transmitter is very close to V8.Its deviation of the transmission frequency is much smaller than SEP1 and its transmission probability is far superior the SEP1 transmitter and close to the V8 transmitter。Using this method could quickly and efficiently get transmit frequency distribution and stability of the transmitters.

5. Summary

Because of the influencing of the apparent resistivity, formation structure, the plant division and depths by frequency, frequency f has been an extremely important role in the electromagnetic method. And it proposes a theoretical basis for this paper.

The sampled data is mathematical analysis to find the standard deviation of each frequency point by Matlab. Then the larger Standard deviation of frequency is curve fitting to give the actual distribution of the emitted frequency.

By the method described, the stability of actual transmission frequency is validated. And the method is focus on the distribution of the transmitting frequency and its probability distribution.

By repeatedly field test, the effectiveness of this method is verified, the actual transmission frequency distribution could be drawn quickly. This method could provide a basis for future inversion calculation and have a guiding role for the transmitter optimization.

Acknowledgements

Authors wishing to acknowledge assistance or encouragement from colleagues, financial support by R&D of Key Instruments and Technologies for Deep Resources Prospecting (the National R&D Projects for Key Scientific Instruments), GrantNo.ZDYZ2012-1-05-01.

References

[1] Q. Di and C. Yang, "Development and application of core technology in deep resource exploration", Bulletin of Chinese Academy of Sciences, vol. 3 **(2012)**, pp. 389.
[2] J. Lin, "Trend of electromagnetic instrumentation for engineering and environment", Geophysical& geochemical exploration, vol. 24, **(2000)**, pp. 167.
[3] Q. Liao, "Features and application range of V8 multi-function electric measurement system", Resources Environment & Engineering. vol. 12, **(2008)**, pp.150
[4] I. J. Won, "A wide—band electromagnetic exploration method —some theoretical and experimental results", Geophysics, vol. 45, **(1980)**, pp. 928
[5] I. J. Won, "GEM-2 —a new multifrequency electromagnetic c sensor", Journal of Environment al and Engineering Geophysics ., vol. 1, **(1996)**, pp. 129.
[6] Zone International, GDP-32/24 multifunction receiver edification sheet [EB/OL] .http://www.zonge.com/Receivers.html.
[7] K. L. Zone, N. R. Carlson, "Nano TEM: a very early time T EM system", International workshop on high resolution geophysics, Tucson, **(1997)**.
[8] G. Liu, "Development of the earth electromagnetic sounding in China", Chinese Journal of Geophysics. vol. 37, **(1994)**, pp. 301.
[9] S. Jin and L. Zhang, "The study of deep sounding in Chinese mainland", Geological Journal, vol. 06, **(2010)**, pp. 808.
[10] D. Wang and Z. Zen, "The application of electromagnetic method in the deep ocean array earth geological research in Liaodong Bay Beach", Oil & Gas Geology, vol. 04, **(2000)**, pp. 293.
[11] F. Yu, "Research on controlling method of high power electromagnetic transmitter power supply", 2013 Asian Pacific Conference on Mechatronics and Control Engineering, Hong Kong, **(2013)** March 26-27.
[12] J. Li, "Ground electric field and electrical prospecting", Chinese Geological Publishing, Beijing, **(2005)**.
[13] Y. Li, "MATLAB communication simulation development manual", National defense industry Publishers, Beijing, **(2005)**.

Authors

Ren Xiguo, 1986-, Hebei, China, Beijing University of Technology, PhD, scientific interest: Power electronic, Communications technology, Switching supply. E-mail: xiaoxifree@126.com

Zhang Yiming, 1964-, Hubei, china, Beijing University of Technology, Professor, PhD, scientific interest: intelligent power management, motor speed control, servo drives, and motor energy conservation. E-mail: ymzhang@bjut.edu.cn; djzh5@163.com; zzhh@hpu.edu.cn

Tao Haijun, 1980, Henan, China, Beijing University of Technology, PhD, taught at the University of Henan Polytechnic University, Lecturer, scientific interest: Power electronic, Communications technology, Switching supply. E-mail: taohj99@hpu.edu.cn

Zhu Xuezheng, 1989-, Anhui, China, Beijing University of Technology, Master, scientific interest: Power electronic, Embedded Systems. E-mail: hpuzhuxuezheng@163.com

