Analysis of active interference on radio station from AC UHV power

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Abstract. The problems of Electromagnetic Interference in Airborne Intelligence Radar Stations near the AC UHV Transmission Lines are researched in this paper, which is mainly active interference. The calculation method for the interferences is analysed, and then the proper protection distances of the AC UHV transmission line to the radar station are given. The paper analyzed the active interference of AC UHV transmission lines, and focuses on the active interference caused by the line corona on the active radar of nearby airborne intelligence when the transmission line is under normal operation. In the end, this paper proposes the recommended values of active interference protection distance for 1000kV AC UHV transmission lines and airborne intelligence radar stations.

1 Introduction

With the rapid development of current science and technology, UHF radio stations(such as analog TV and digital TV broadcasting station, military aviation radars, etc.),which have strict requirements on the surrounding electromagnetic environment. The solution of passive interference of these stations with UHV transmission lines with large size metal structures has become a research hot spot[1,2].

The air-to-air intelligence radar is the radar which used to search, monitor, identify airborne targets and determine their coordinates and motion parameters, it also known as the air-to-air search radar[3].It is an important electronic technology for acquiring air target information in modern warfare equipment.

The paper analyzed the active interference of AC UHV transmission lines, and focuses on the active interference caused by the line corona on the active radar of nearby airborne intelligence when the transmission line is under normal operation. And then, this paper proposes the recommended values of active interference protection distance for 1000kV AC UHV transmission lines and airborne intelligence radar stations.

2 Analysis of active interference of transmission lines and airborne radar stations

The operating frequency of the radar[3].The operating frequency of the applicable radar has been extended from the high frequency band(3MHz to 30MHz)to the millimeter band(30GHz to 300GHz) .The

air-to-air intelligence radar studied in this paper is a commonly used in China. The frequency is 80MHz to 3000MHz, which can be divided into two frequency bands: 80MHz to 300MHz and 300MHz to 3000MHz. The definition of guard spacing and the guard spacing limit[4] are given in GB13618-1992" Electromagnetic Environment Protection Requirements for Airborne Information Radar Stations". Table 1 shows the spacing between the overhead power lines and the airborne intelligence radar stations at different voltage levels. If it cannot meet the requirements of Table 1 or special circumstances, it can be calculated according to the electromagnetic environment protection criteria of the air intelligence mine station. The interference effects of high-voltage overhead transmission lines and substations considered in the electromagnetic environment protection criteria mainly come from two aspects: First, the high-voltage overhead transmission lines, substations, etc. in the live operation, will produce radio interference; Second, the high-voltage overhead transmission lines, towers and other facilities are used as obstacles, if they are too close to the radar station, it will destroy the requirement of the reflector surface of the radar array, which will cause the deformation of the radar lobe and affect the detection performance. In addition, high-voltage overhead transmission lines, towers and other facilities will also cause a certain shielding angle or electromagnetic wave attenuation of the radar, which may cause the missing radar target or detection distance. According to GB13618-92 "Electromagnetic Environment Protection Requirements for Airborne Information Radar Stations"[4] (hereinafter referred to as "Standard 1") and GJBZ20195-3 "Selection Criteria for Military Ground Radar Positions"[5] (hereinafter referred to as "Standard 2") ,the protection spacing for

radar overhead transmission lines can be calculated separately. The larger one is the final guard spacing value.

Table 1. The protection space between overhead transmission line and intelligence radar station

		Protective spacing	
		80~300MHz	300～3000MHz
High-voltage overhead transmission lines	500kV	1.6km	1.0km
	330~330kV	1.2km	0.8km
	110kV	1.0km	0.7km

For the radio interference level of High-voltage overhead transmission lines above 30MHz, the above has mainly come from accidental factors such as sparks discharge of iron towers, insulators strings, and metal fittings. At present, there is no effective calculation and prediction method, and only through actual measurement.

The measuring instrument uses SCHWARZBECK 9k~3000MHz receiver, supporting 30MHz~300MHz broadband double-cone antenna and logarithmic period antenna of 200MHz~1000MHz frequency band. The radio interference quasi-peak of the antenna in both the vertical and horizontal polarization directions was measured in the measurement[6].

Since the radio interference level above 30MHz is very low, the method of comparative measurement under the condition that the test line segment is charged and not charged id adopted. The data measured under the condition that the line segment is not charged is the background radio noise, and by comparison, it is concluded whether the radio interference of the UHV transmission line in this frequency band is significant[7-8]. Figure 1 shows Radio interference quasi-peak spectrum in the 30 MHz to 1000MHz band .Figure 2 shows the influence of antenna polarization direction on measuring results.

Radars generally operate in ultrashort waves and above, and are therefore mainly affected by high frequency noise pulses. The mechanism of radar being reduced by noise interference[3] is as fellow: the interference noise from the transmission line enters the radar receiver and is superimposed on the internal noise, reducing the signal-to-noise ratio, causing the radar to reduce the target discovery probability. To maintain the same probability of discovery and false alarm probability, the power of the minimum detectable signal must be increased, but this will reduce the detection rang of the radar.
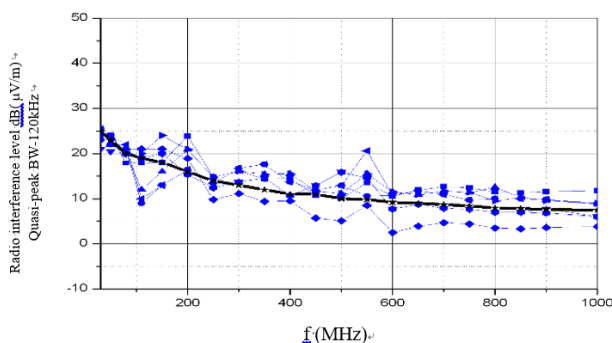
Fig.1 Radio interference quasi-peak spectrum in the 30 MHz~1000MHz band
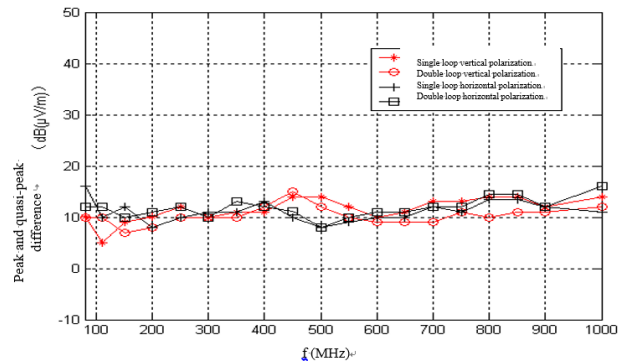
Fig. 2 The influence of antenna polarization direction on measuring results

Figure 3 and 4 summarize two typical comparative measurements. Both measurements were performed in good weather. The measurements did not distinguish between the radio interference levels before and after charging. Therefore, it can only be explained that the UHV line has low radio interference level in this frequency band and is completely submerged in background radio noise[9,10]. Background radio noise is mainly caused by unstable factors such as space radiation and meteorological activities, so that it is presented in an Irregular fluctuations with a small range.

The observation of the iron tower the insulator string, the fittings, etc, of the test line segment by the ultraviolet image also did not clearly reveal the portion where the spark discharge exists(this is an observation made for the specific measured object).
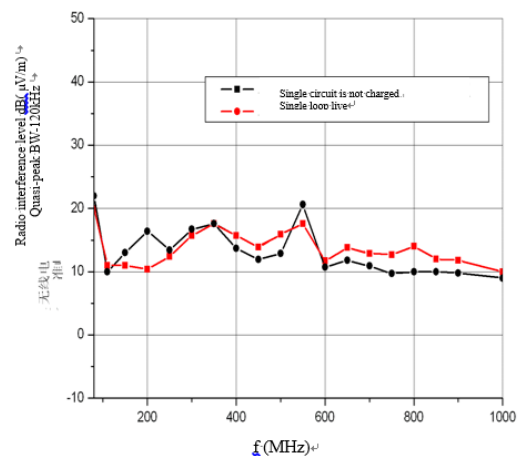
Fig . 3 Comparison I of the radio interference level before and after Charged (vertical polarization)
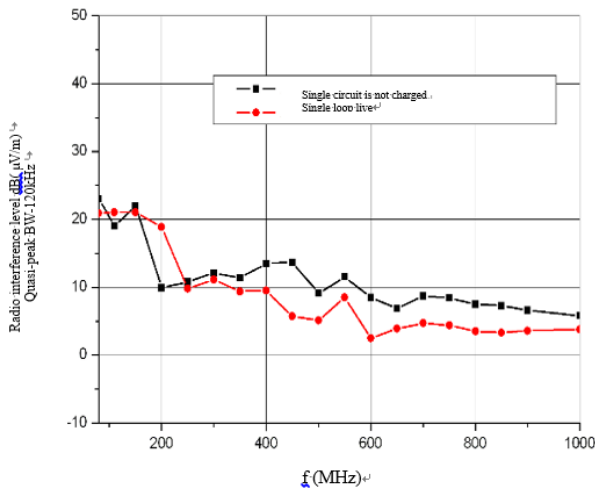
Fig. 4 Comparison II of the radio interference level before and after Charged (vertical polarization)

The measurement results show that the difference between the active radio interference generated by the UHV transmission line and the background noise is very small. Therefore, the impact on radar at working frequencies above 80MHz is very small. The guard spacing can follow the active guard spacing of the 500kV transmission line. That is, the guard spacing is 1600m when the working frequency is 80MHz~300MHz; the guard distance for the radar up to the operating frequency of 300MHz~3000MHz is 1000m.

3. Simulation test of the influence of transmission lines on radar

The test of the influence of obstacles such as UHV transmission line routes and towers on radar detection performance is most ideally carried out on actual circuits. Considering that the transmission line and the tower itself are relatively large, it is difficult to carry out the physical test. Therefore, the" scaling ratio" method is used for the simulation test.

According to Wang Qi, Zhao Jie, and Zhao Zhibin's research on the "passive interference of 800kV DC transmission lines to the radio stations in the short-wave band", the parameters set in this paper are as follows. The experimental prototype is a "drum type" iron tower. The ratio is 30:1, the tower height is about 100m (100/30m in the test), the transmission line adopts 8 split double loop form, the wire splitting pitch is 400/30mm, and the wire type is 8×LGJ-500/35 aluminum cable steel reinforced. Stranded wire with a wire radius of 16/30mm and a pitch of 500/30m. The ground wire is aluminum cable steel reinforced with a grounding resistance of no more than 15Ω. During the test, a 3-pitch 4-tower model was selected for testing.

The transmitting antenna and receiving antenna adopt the double-ridged horn antenna with working frequency band of 1~18GHz, its average gain is 11.3dB, the impedance is 50Ω,the maximum power is 300W,and the peak power is 500W. The power of the transmitted signal source is E8257D with a maximum output power of 10dBm and a maximum operating frequency of

40GHz. The receiver uses the E4408B spectrum analyzer and its operating frequency range is 9kHz~26.5GHz. The signal source and the transmitting antenna and the spectrum analyzer and the receiving antenna are respectively located in the two sides of the transmission line and the tower, the signal source is connected with the transmitting antenna, and the spectrum analyzer is connected with the receiving antenna[3]. The test layout is shown in Figure 5.
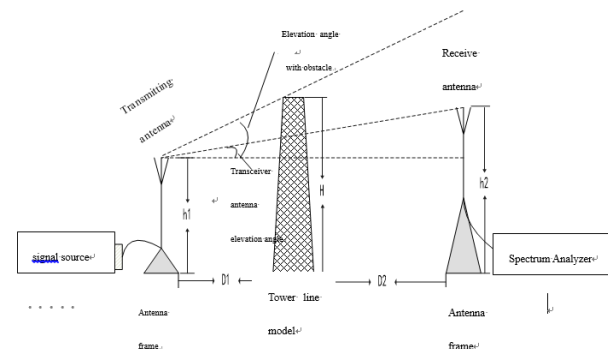
Fig.5 Layout of measurement

Where: $D1$ ——distance between the transmitting antenna and the tower line model, units: m; $D2$ —— distance between the receiving antenna and the tower line model, units: m; $h1$ ——the height of the transmitting line, units: m; H ——the height of the tower and line model, units: m; $h2$ ——the height of the receiving line, units: m; α ——the elevation angle between the transmitting antenna and the obstruction highest tangent, in degree; β ——the elevation angle between the connecting line of the transceiver antenna and the horizontal line, in degree.

The main parameters are set as follows: based on the source power and the receiving distance, the distance between the transmitting antenna and the receiving antenna is determined, that is , $(D1+D2)$ is 100m, test frequency selection 3GHz, 7GHz and 12GHz. During the test, follow the steps below.

- Testing the propagation characteristics of electromagnetic waves in free space.
  Select the open space, fix the transmitting antenna and receiving antenna at intervals of 100m,the transmitting antenna frame height is 1.5m; when the transmitting signal frequency is set to 3GHz, 7GHz and 12GHz respectively, The corresponding erection height of the receiving antenna is 2.1m, 2.5m, 3m and 6m respectively. Record the power indicator displayed by the spectrum analyzer;
- Testing the effect of iron tower on the propagation characteristics of electromagnetic waves.
  Keep the setting parameters of the spectrum analyzer and the output power of the signal source unchanged, and set the position of the receiving antenna and transmitting antenna unchanged. The tower model is set at 70m, 50m, 30m and 10m from the transmitting antenna

respectively. The corresponding erection height of the receiving antenna is 2.1m, 2.5m, 3m and 6m respectively. Read the power indicator displayed by the spectrum analyzer;

- Testing the influence of iron towers and transmission lines in the propagation characteristics of electromagnetic waves.

Keep the setting parameters of the spectrum analyzer and the output power of the signal source unchanged, and set the position of the receiving antenna and the transmitting antenna unchanged. Set the assembled iron tower and transmission line models at positions 70m, 50m, 30m, and 10m away from the transmitting antenna. Record the power indicator displayed by the analyzer.

The test results show that when the transmission frequency is 12GHz, only the tower has a larger attenuation of the received signal than when there is a tower cable. The reason is that when the tower attenuation test is performed, the front of the tower is opposite to the transmitting and receiving antennas, and when there is a tower cable test, the minimum face of the tower is opposite to the transmitting and receiving antennas, resulting in the above results. From the test results, the mainly the influence of the transmission line is the line, and the tower has less influence on the signal transmission. If there is a high-voltage transmission line between the radar and the target, the echo signal received by the radar will pass through the transmission line twice. Since it is difficult to achieve a six-fold increase in the conductivity of the model, the absorption loss of the radar wave by the steel material used in this test model is about 2-3 times larger, so the test results may be stricter.

3 Conclusion

In summary, Since the actual measurement shows that the UHV transmission line has a low radio interference level above 80MHz in the radar operation, it is basically submerged in the background radio interference noise, and even if it is strictly considered, it will not exceed the current 500kV transmission line. The active interference protection distance of the radar to the UHV transmission line can be implemented according to the requirements of the protection spacing of the 500kV transmission line in" Standard 1", and the protection distance between the UHV transmission line and the radio station is 1600m. When using a 1000kV UHV single-circuit transmission line, the guard spacing is 2400m. If the height of the radar position is significantly higher than the average height of the transmission line conductor, the protection distance of the meter wave radar to satisfy the effective reflection surface is 2400m, and the remaining radars can satisfy the active interference protection distance of

1600m. However, before determining the protection distance between the 1000kV UHV transmission line and the air-to-air radar station, it is also necessary to negotiate with the radar station management department. In the specific implementation, if it is difficult to ensure the protection spacing, other areas can be negotiated and resolved in the case that the main responsibility area is satisfied to meet the above requirements.

Acknowledgement

References

1. Yin Hui, Zhang Xiaoming, Wang Yantao, et al. Research on 3D Visualization of Electromagnetic Interference for Ultra-high Voltage Transmission Lines[J]. High Voltage Engineering, **40**, 12, 2014.

2. Yang Jiawei, Tang Bo, Huang Li, et al. Research on Interference between UHV Power Transmission Lines and Air Defense Surveillance Radar Station[J]. Journal of China Three Gorges University, 2018.

3. Ding Lufei, Geng Fulu, Chen Jianchun, et a. Radar principles[M]. Beijing. Publishing House of Electronics Industry, 2014.

4. GB13618-92. Electromagnetic Environment Protection Requirements for Airborne Radar Stations[S]. Beijing. Standard Press of China, 1992

5. GJBZ20195-3. Selection Criteria for Military Ground Radar Positions[S]. Beijing. Standard Press of China, 1993

6. Gan Zheyuan, Wang Yanhai, Zhang Jiangong, et al. Suppression of HF Passive Interference in Transmission Lines by Using Magnetic Tube[J]. high Voltage Engineering, **43**, 5, 2017.

7. Xiang Tao, Hu Yuxian. The electromagnetic Environment Test of the Navigation Station of the Airport in Dazhou, Sichuan Province[J]. China Radio, **11**,1, 2017(11)

8. Zhao Jiahao. Causes and Treatment of Wireless Electromagnetic Wave Interference[J]. Electronic Technology and Software Engineering, **21**, 1, 2017

9. GB6364－86 Aeronautical Radio navigation Station Electromagnetic Environment Requirements[S]. Beijing. Standard Press of China, 1986

10. GB15707-1995 High-voltage AC Overhead Transmission Line Radio Interference Limit [S]. Beijing. Standard Press of China, 1995