Technical Analyses of the Interference Effect of "Advanced Radar"

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Abstract – The conception of "advanced radar" is introduced and put forward, while it is proved that the weakpoints of interference can still be employed. Meanwhile, the paper expounds the principle how Over-The-Horizon Radar(OTHR) works, and derives the OTHR interference equation. By listing the OTHR examples, it analyzes and calculates the equivalent power of the OTHR and the sensitivity of the receiver to build up a block diagram how the interferencer is structured. Hence, the effective area is achieved, and OTHR can be intereferenced effectively with not so high equivalent power.

Key words – *OTHR*; *interference*; *advanced radar*

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1 Introduction[1]

"Advanced radar" has not yet seen a clear definition now. The author proposes that it should include three types of radar: the radar made in the new system with improved performance and parameters, ultra-long-range radar and OTHR. The first one is advanced for its new system and high performance. While ultra-long-range radar detects the target thousands of kilometers away which works like a telescope, OTHR not only covers the detection range of 1 000 km~3 000 km, but also effectively detect stealth aircraft. Therefore they can be called "advanced radar."

The new system radar includes pulse compression, pulse Doppler, synthetic aperture, phased array and frequency agile radars. These radars can be modified by increasing their detection range, raising the ability to distinguish the radar range and angle to enhance the radar angle tracking accuracy and tracking volume, raising the target recognition and anti-jamming capabilities, while reducing their size and weight, increasing reliability and working lifetime. All these modifications are added to the definition of "advanced radar".

From the point of view of interference, no matter how advanced they are, radars still can not hide their following inherent weaknesses:

1) Whether useful or harmful signals, as long as they reach operating frequency band, can be received by the radar receiver;

2) Regardless of how the radar signal processing, if the advanced signal amplitude, as long as the harmful signals stronger than the useful signal range as large as a certain multiples of the signal processing system, that radar can not effectively extract useful signals;

3) Whatever the radar antenna system or a phased array antenna uses what kinds of techniques measures, such as side lobe cancellation, low-side lobe phased array antenna technologies, the radar antenna side lobe level can not be zero.

Due to these weaknesses of radars, even the "advanced radar" still can be effectively interfered.

Now an example of OTHR is to demonstrate the effect of its interference.

1.1 The basic working principle of OTHR[2-3]

OTHR discovers horizon targets with the characteristics of radio wave reflecting encountered targets on the ionosphere(as shown in Fig. 1)

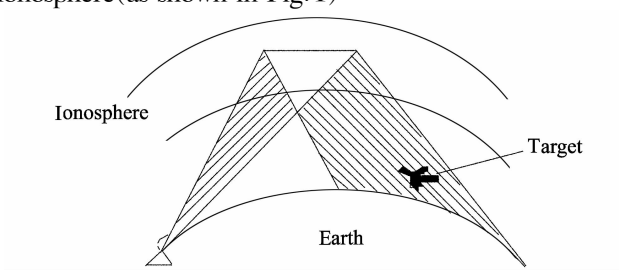

Fig. 1 Drawing about detection of targets of OTHR

The effective range of OTHR discovering targets(as shown in Fig. 2) OTHR equation can be written as

$$P_r = \frac{P_{av} G_t G_r \sigma_t \lambda^2}{(4\pi)^3 R_p^4} L_s L_p T_c, \quad (1)$$

where R_p is radar-ray range, m; P_{av} is average power of radar transmitter; G_t is transmitting antenna gain of radar; G_r is receiving antenna gain of radar; σ_t is scattering cross-sectional area of the target, m^2; λ is radar wavelength, m; T_c is coherent accumulation time, S; L_S is loss coefficient of radar equipment; L_p is ionospheric propagation path loss.

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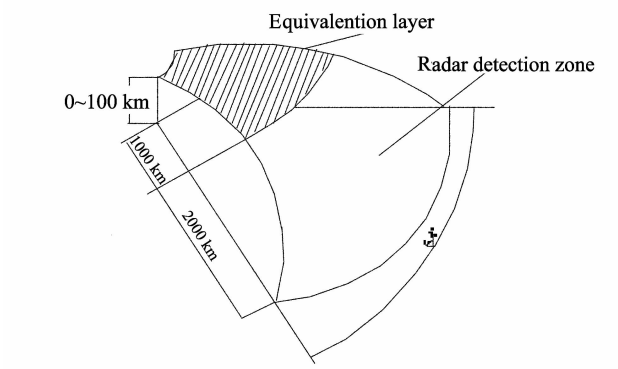

Fig.2 Drawing about detection range of OTHR

The frequency range of the OTHR is 5～30 MHz. In order to meet the time ionospheric variability OTHR has to change the frequency at any time. G_t, G_r is a function of the operating wave length; λ and L_p are a function of distance and time. This shows that the parameters of inter-dependence is diverse.

σ_t is the radar scattering cross-sectional area which is a function of frequency, polarization and posture. In particular, there is a big change with the operating frequency. T_c is the coherent accumulation which is limited by the beam scanning time and cannot be too much.

P_N is the interference signal power received by OTHR.

$$P_N = \frac{P_j G_j}{4\pi R_{jp}^2} \frac{\lambda^2}{4\pi} G_r(\theta) L_{js} L_{jp} T_{jc} L_{jN}, \tag{2}$$

where $P_j G_j$ is interference equivalent radiation power; R_{jP} is jammer to the radar-ray range; λ is machine operating wavelength interference, m; $G_r(\theta)$ is radar receiver side lobe level; T_{jc} is interference stacked; L_{js} is interference with aircraft equipment loss coefficient; L_{jP} is Interference signal ionospheric propagation loss; L_{jN} is polarizational interference loss; K_{jP} is interference suppression ratio.

$$K_{jp} = P_N / P_r, \tag{3}$$

Take Eq.(1) into Eq.(3),

$$K_{jp} = \frac{P_N}{P_r} = \frac{\dfrac{P_j G_j \lambda^2 G_r(\theta) T_{jc} \Delta F_o}{4\pi R_{jP}^2 L_s L_p L_{jN}}}{\dfrac{P_{aV} G_t G_r \sigma_t \lambda^2 T_c \Delta f_o}{(4\pi)^3 R_p^4 L_{jS} L_{jP}}}, \tag{4}$$

which could be simplified to

$$K_{jp} = \frac{4\pi P_j G_j R_p^4}{P_{aV} G_t R_{jP}^2 \sigma_t} \frac{G_r(\theta)}{G_r} \frac{T_{jC} L_{jS} L_{jP} \Delta F_o L_{jN}}{T_C L_S L_P \Delta f_o}, \tag{5}$$

Then, the required equivalent power needed for the interference

$$P_j G_j = \frac{K_{jP} P_{aV} G_t R_{jP}^2 \sigma_t}{4\pi R_P^4} \frac{G_t}{G_r(\theta)} \frac{T_C L_S L_P}{T_{jC} L_{jS} L_{jP}} \frac{1}{L_{jN}} \frac{\Delta f_o}{\Delta F_o}. \tag{6}$$

1.2 The development of profiles about OTHR of oversea

Raytheon company in the United States started to develop the first OTHR in 1984, which was appraised in 1989, and put to work in 1993. its parameters are shown in Tab.1.

Tab.1 Parameters of AN/TPS-71

Model	Operating frequency	Detection distance range	Bearing fan	T/R pairs of bases	Transmitter average power
AN/TPS-71	5～28 MHz	900～3 000 km	64°	92～185 km	200 kW

From then on, USA and other countries carried out plans to design and produce OTHR. Here are some examples of OTHR from USA, Russia and Australia.

AN/FPS-118 OTHR (U.S.)

Parameters of AN/FPS-118 OTHR are shown in Tab.2. Its transmitting station using phased-array antenna, 60 m high, both high and low frequencies of 16 different units of the log periodic dipole antenna array, low-frequency 5～12 MHz; high frequency 10～28 MHz; with a total array aperture of 366 m (FPS-118 launch Tianbo caliber 1 080 m). Receiver array is composed of 272 pairs of the overall caliber 2.6 km, beam width is 0.5°.

Tab.2 Parameters of AN/FPS-118 OTHR

Model	Frequency	Detection distance range	beam width	Average power
AN/FPS-118 OTHR	5～28 MHz	800～2 880 km	2.75°	100 kW

LADOGA-the-horizon radar (Russia)

Parameters of LADOGA-the-horizon radar are shown in Tab.3. The time to find and determine the target ≤5 min; the number of target tracking is 400 groups, LADOGA-the-horizon radar also have antennas of two groups (high and low), eight transmitters with a total diameter of 220 m.

Tab.3 Parameters of LADOGA-the-horizon radar

Frequency	Bearing fan	Peak power	Detection range	Ranging error	side angle error
5～28 MHz	60°	0.6～1 MW	900～3 000 km	15～20 km	1°～1.5°

OTHR (Jindal company, Australia)

Parameters of OTHR produced by Jindal company in Australia are shown in Tab.4.

Tab.4 Parameters of OTHR produced by Jindal company in Australia

Detection distance range	Bearing fan	Operating frequency range	T/R pairs of points away from	Average transmission power
1 000～3 000 km	60°	6～26 MHz	100 km	560 kW

2 Self-interference about OTHR

Self-interference about OTHR of the diagram is shown in Fig. 3. Self-interference means that the jammer was installed in the protected targets.

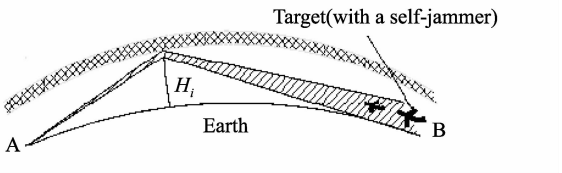

Fig. 3 Drawing about Interference OTHR with self-jammer

Supposing that transmitter power of OTHR is 300 kW; antenna gain of 30 dB; operating frequency of 5~30 MHz; bearing fan 60°; receiving antenna gain of 35 dB; T/R tin station composed of pairs of base station.

$$G_r/G_r(\theta) = 1.$$

According to Eq. (5), $K_{jP} = 100$, $R_{jP} = R_P$.

In the interference conditions, $L_{jS} = 0.5$, $L_{jP} = 0.2$, $L_S = 0.5$, $L_P = 0.1$, $\Delta f_0/\Delta F_0 = 0.3$, $L_{jN} = 0.5$; $\sigma_t = 100\ \mathrm{m}^2$; $R_{p\min} = 1\ 000$ km.

Take parameters into Eq. (5),

$$P_jG_j = \frac{10^2 \times 300 \times 10^3 \times 10^3 \times 10^2}{4\pi(1 \times 10^6)^2} \cdot \frac{0.5 \times 0.2 \times 0.3}{0.1 \times 0.3 \times 0.5} = 500\ \mathrm{mW}.$$

Set jammer power 1 W; then the transmitting antenna azimuth, 360°, elevation, 45°; gain of 1. A single rack made by a self-jammer aircraft can cover an area of 45×45=2 100 km^2 to 18 900 km^2. Thus, one self-jammer aircraft can cover a fleet distributed in 45×45 km^2. The interference of distributed covering by OTHR jamming is shown in Fig. 4.

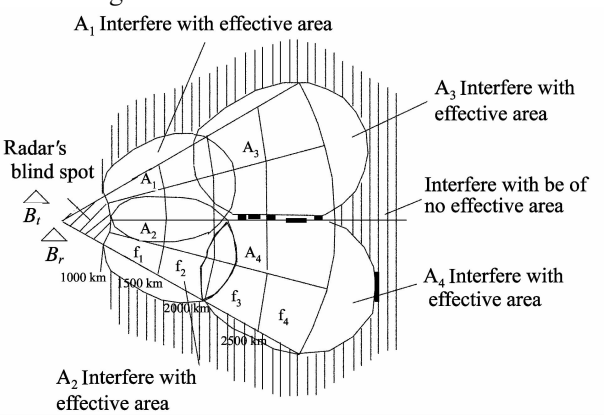

Fig. 4 Interference of distributed covering by OTHR jamming

Where $K_{jP} = 100$; $P_{aV} = 300$ KW; $G_t = 1\ 000$; $\sigma_t = 100$; $\frac{G_r}{G_r(\theta)} = 1\ 000$; $(\pm 20°)$ $L_{jS} = 0.5$; $K_f = 0.3$; $L_j = 0.5$; $L_S = 0.5$; $L_{jN} = 0.5$; $L_P = 0.1$; $R_{jP} = 2\ 000$ km; $R_P = 1\ 000$ km; $\sigma_t = 100\ \mathrm{m}^2$; $R_{p\min} = 1\ 000$ km.

$$P_jG_j = \frac{K_{jP}P_{aV}G_tR_{jP}^2\sigma_t}{4\pi R_P^4}\frac{G_t}{G_r(\theta)}\frac{T_CL_SL_P}{T_{jC}L_{jS}L_{jP}}\frac{K_f}{L_{jN}} = \frac{10^2 \times 3 \times 10^3 \times 4 \times 10^{12} \times 10^2 \times 10^3 \times 2}{12.6 \times 10^{24}} = 20\ \mathrm{W}.$$

Select the jammer power of 50 W; transmitting antenna gain of 1 (azimuth 360°; elevation of 45°). Then the receiver sensitivity P_{jr} of the interferer is

$$P_{jr} = \frac{P_{av}G_t(\theta)}{4\pi R_{jP}^2}\frac{\lambda^2}{4\pi}G_jL_SL_P. \tag{7}$$

Set $P_{aV} = 300$ kW; $G(\theta) = 1$; $\lambda = 10$ m; $G_j = 1$; $L_S = 0.5$; $L_P = 0.1$; $R_{jP} = 3\ 000$ kM, then

$$P_{jr} = \frac{300 \times 10^3 \times 1 \times 10^2 \times 0.5 \times 0.1}{1.5 \times 10^2 \times 9 \times 10^{12}} = -91\ \mathrm{dBW}. \tag{8}$$

As seen from the calculation and analysis of the self-jamming aircraft, the equivalent power required for interference is about 0.5 W; from that of the covering jammer interference it is about 20 W; the receiver sensitivity is about −91 dBW. The jammer needs rapidly aiming carrier frequency band, and all these technical goals can be achieved. The block diagram of a basic jammer working principle is shown in Fig. 5.

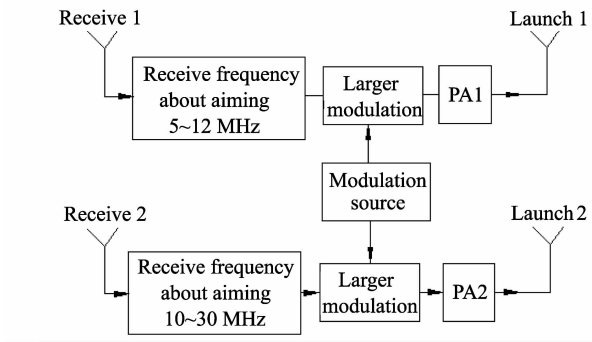

Fig. 5 Block diagram of a basic jammer working principle

3 Conclusion

The OTHR has many advantages. It not only detects targets in the distance, but also covers a large detecting region and finds stealth aircrafts. However, inherent weaknesses still exist for OTHR as it is radio equipment, and it is easy to achieve effective interference.

References

[1] Guoqin Zhao, 1999. Radar Countermeasure Theory. Xi'an Electronic Science and Technology University Press, China, p. 10.

[2] Wenyun Zhou, Peinan Jiao, 2007. OTHR technology, Electronics Industry Press, China, p. 12.

[3] M I Skolnik, 1990. HardBook Radar. Second Edition. McGraw-Hill, New York.