International Conference on Logistics Engineering, Management and Computer Science (LEMCS 2014)

Ultra-Wideband Radio Fuze Target Signal Characteristic Research

Shen Lei
Mechatronical Engineering,
Beijing Institute of Technology
Beijing,
matouzi417@bit.edu.cn

Huang Zhonghua
Mechatronical Engineering,
Beijing Institute of Technology
Beijing,
huangzh@bit.edu.cn

Abstract—Due to the radiation of Ultra wideband signal、Surface scattering and Ultra wideband radio fuze target signal frequency,the Ultra wideband radio fuze target signal always submerged in the noise,it is necessary for us to study the characteristics of Ultra wideband radio fuze target signal.Starting from the diffuse reflection characteristics and multipath effects of ultra wide band signal, Derivation Ultra wideband radio fuze target signal mathematical expressions and model mathematical modeling.Simulate the ultra wideband radio fuze target signal with the help of Computer Simulation Technology(CST) and Matlab. The simulation results show that compared with the emission signal, target signal with the broadening effect is obvious, and consistent with the measured signal. The simulation results are basically consistent with the real test results.

***Keywords-** Ultra wideband Fuze;Ultra wideband antenna; target signal;Simulate ;Broadening effect*

I. INTRODUCTION

Due to the radiation of ultra wide band signal、special scattering and characteristics of fuze near field work,there is a big difference between the fuze received and transmitted signals.The target signal frequency of Ultra wideband radio fuze up to several GHz and always submerged in noise,so it is very hard to get the measured waveform signal, it is very difficult for Fuze receiver and signal processing circuit design. In order to provide theoretical guidance for the fuze receiver and signal processing circuit design, we are in urgent need of theoretical research on ultra wideband radio fuze target signal[1].

Currently, the research on ultra wideband radio fuze target signal is not very thorough, in general,the problems on encountered in the study of ultra wideband radio fuze target signal are:

When the target of fuze is the ground, the ground scattering signal back to the time of fuze antenna is inconsistent because of in the range of each scatterer distance is different between the fuze antenna and antenna beam,so it will cause the broadening effect of the ground target signal, the signal pulse width of ultra wideband radio fuze radiated is morenarrow,the effect will be more obvious,this effect called multipath effects of ultra wide band signal

The ground is distributed reflection typical target,it is composed of a large number of scatterers and absorbers, reflector assembly, when an electromagnetic wave is incident to the ground,it will cause the electromagnetic reflection, scattering and the target medium absorption and polarization phenomenon.Mainly in two cases: the electromagnetic wave of specular and diffuse reflectance..Because of the scattering characteristics of the ground,it is difficult o the modeling of UWB radio fuze target signal[2-4].

II. THE GROUND SCATTERING CHARACTERISTIC

The ground is composed from a large number of scatterers absorbers and reflector, is stributed reflection target.It will lead electromagnetic field reflection,scattering and absorption of medium and the target polarizationphenomena,when electromagnetic waves incidence to the ground, mainly manifested as two cases electromagnetic wave of specular and diffuse. When the surface waviness h and the Complementary angle of incidence angle csatisfy “(1)”,we can see the target as a smooth surface, electromagnetic wave generating specular reflection, in accordance with the laws of Reflection theorem of geometrical optics,otherwise,we can see the surface as rough surface.

$$h < \frac{c}{16 f \sin \theta'} \tag{1}$$

“(1)”is Rayleigh criterion.We can see that when the radiation signal radiation to the target surface, the target target signal performance for the specular or diffuse reflection, mainly depends on the degree of surface relief objects, electromagnetic wave incident angle and frequency of signal. The input signal frequency is higher, the conditions of specular reflection target fluctuation is smaller, target surface should be more smooth.

For the surface not satisfy the “(1)”,the reflection can be seen as the specular component and the diffuse reflection component. In the case of vertical incidence,the out proportion of rough surface as:

$$\exp[-2(\frac{2\pi\sigma_{\mathrm{h}}}{\lambda})^2] = \exp[-2(\frac{2\pi\sigma_{\mathrm{h}} c}{f})^2] \tag{2}$$

In “(2)”, σ_{h} is rough surface root mean square height.

The Figure 1.shows the expression (2), the abscissa is $\sigma_{\mathrm{h}}/\lambda$.We can see that if the wave of incident wave is fixed,the surface is more rough,the specular reflection component is less.When $\sigma_{\mathrm{h}} = 0.1\lambda$ the specular reflection component is 37.73%,when $\sigma_{\mathrm{h}} = 0.2\lambda$ the specular reflection component is 2.03%.

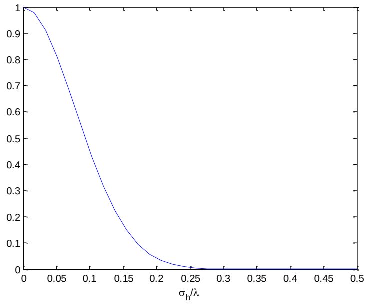

Figure 1.Rough surface specular reflectance ratio

For UWB radio fuze, If the lowest frequency signal for antenna radiation is 1GHz,the wavelength is 0.3m,when the ground height distribution variance is 6cm, specular reflection ratio is 2.03%; when the ground height distribution variance is 3cm, specular reflection ratio is 37.73%. If the signal peak frequency is 2.7GHz, the ground height distribution variance is 2cm, specular reflection ratio is 2.03%, the ground height distribution variance is 1cm, specular reflection ratio is 37.73%.The UWB radio fuze’s diffuse reflection energy accounted for most of the total reflection energy,the ground reflection approximately as the completely diffuse reflection,as the Figure 2. shows[5-7].

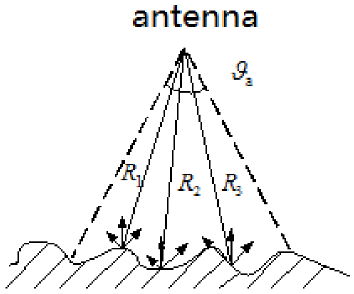

Figure 2.Antenna diffuse reflection

III. GROUND TARGET SIGNAL MODELING

A. UWB radio fuze signal derivation

We assume the ground is the rough surface,this surface is composed of a plurality of uniform placement of independent scatterers.On the basis of this model,we can derive the UWB target signal.

The UWB radio fuze ground target signal is generated from plenty of uniform distribution independent scatter, the ground of the impulse response as “(3)”.The excitation signal of antenna is Gauss two derivative,we can obtain the UWB radio fuze target signal $w(t)$ as “(4)”

$$h(t) = \sum_{i=1}^{M} a_i \delta(t-\tau_i) \tag{3}$$

$h(t)$ is the target impulse response，a_i is target signal attenuation；τ_i is echo delay，$\tau_i = \dfrac{2R_i}{c}$。

$$w_{\mathrm{r}}(t) = \frac{1}{R_i^2} w(t) * h_{\mathrm{tp,I}}(t,\theta,\phi) * h_{\mathrm{rp}}(t,\theta,\phi) * \sum_{i=1}^{M} d_i \delta(t-\tau_i) \tag{4}$$

$w(t)$ is Gauss two derivative，$h_{\mathrm{tp,I}}(t,\theta,\phi)$ is the transmitting antenna impulse response, $h_{\mathrm{rp}}(t,\theta,\phi)$ is the receiving antenna impulse response.

sign

$$s(t,\theta,\phi) = w(t) * h_{\mathrm{tp,I}}(t,\theta,\phi) * h_{\mathrm{rp}}(t,\theta,\phi) \tag{5}$$

“(4)” change to

$$w_{\mathrm{r}}(t) = \frac{1}{R_i^2} s(t,\theta,\phi) * \sum_{i=1}^{M} d_i \delta(t-\tau_i) = \sum_{i=1}^{M} \frac{d_i}{R_i^2} s(t-\tau_i,\theta,\phi) \tag{6}$$

The impulse response of each scattering amplitude attenuation coefficients are equal， sign as d the amplitude attenuation coefficient of unit area is:

$$d_0 = \frac{\sum_{i=1}^{M} d_i}{A} = \frac{Md}{A} \tag{7}$$

Due to the fuze number of scattering M is proportional to the area of irradiation area A,make $k = \dfrac{M}{A}$ k is the constant,we can get

$$d_0 = kd \tag{8}$$

For narrowband radar equation,we callde the ratio of the total scattering cross section and the area A is target scattering characteristic ,signed as:

$$\sigma_0 = \frac{\sum_{i=1}^{M} \sigma_i}{A} = \frac{M\sigma}{A} = k\sigma \tag{9}$$

From $\sigma = \lim_{R\to\infty} 4\pi R^2 \left|H(jw)\right|^2$,can conclude the relation between the single scattering RCS and the amplitude of target impulse response[8.9].

$$a = \frac{\sqrt{\sigma}}{2R\sqrt{\pi}} \tag{10}$$

and

$$d = \frac{\sqrt{\sigma}}{2\sqrt{\pi}} \tag{11}$$

From “(8)”、“(9)”and“(11)”

$$d_0 = \frac{1}{2}\sqrt{\frac{k\sigma_0}{\pi}} \tag{12}$$

B. UWB radio fuze target signal modeling

The geometry relation between fuze antenna and ground shown as Figure 3.xoy express ground,D express fuze,E is the intersection of elastic axis and xoy,H is height from fuze to ground,dA is surface element,R is distance from fuze to dA[10].

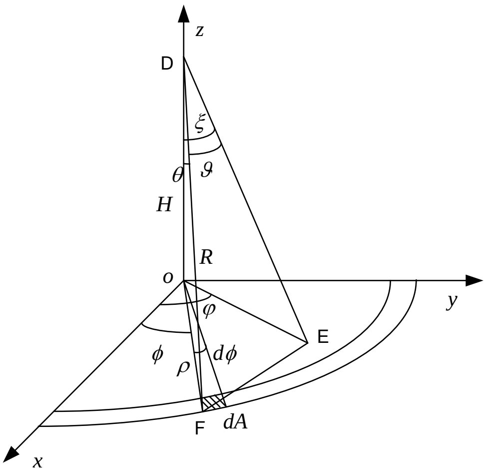

Figure 3.Diagram between fuze antenna and ground

The attenuation coefficient d_0 is the function about θ,sign as $a_0(\theta)$， The attenuation coefficient of dA is $a_0(\theta)dA$.We can get the target signal about dA:

$$\begin{aligned} dw_{\mathrm{r}}(t) &= \frac{1}{R^2} w(t) * h_{\mathrm{tp,I}}(t,\theta,\phi) * h_{\mathrm{rp}}(t,\theta,\phi) * \delta(t-\tau_i) d_0(\theta) dA \\ &= \frac{1}{R^2} s(t-\tau_i,\theta,\phi) d_0(\theta) dA \\ &= \frac{1}{2R^2}\sqrt{\frac{k\sigma_0(\theta)}{\pi}} s(t-\tau_i,\theta,\phi) dA \end{aligned} \tag{13}$$

Express the target signal as integral:

$$w_{\mathrm{r}}(t) = \int_A \frac{1}{2R^2}\sqrt{\frac{k\sigma_0(\theta)}{\pi}} s(t-\tau_i,\theta,\phi) dA \tag{14}$$

From Figure3, $dA = \rho d\rho d\phi$, $R = \sqrt{H^2+\rho^2}$, "(14)"change to:

$$w_{\mathrm{r}}(t) = \frac{1}{2}\sqrt{\frac{k}{\pi}} \int_{\phi_{\min}}^{\phi_{\max}} \int_{\rho_{\min}}^{\rho_{\max}} \frac{s(t-\frac{2\sqrt{H^2+\rho^2}}{c},\theta,\phi)\sigma_0(\theta)}{H^2+\rho^2} \rho d\rho d\phi \tag{15}$$

ρ 、ϕ is related to the range of integration and the angle of antenna|、the antenna beam width.

When the projectile vertical incidence, $R = H/\cos\theta$, $\rho = Htg\theta$, $dA = \rho d\rho d\phi = \dfrac{H^2 \sin\theta}{\cos^3\theta} d\theta d\phi$,

The antenna half power beam width is ϑ_{a} , "(15)"change to:

$$w_{\mathrm{r}}(t) = \frac{1}{2}\sqrt{\frac{k}{\pi}} \int_0^{2\pi} \int_0^{Htg(\vartheta_a/2)} \frac{s(t-\frac{2\sqrt{H^2+\rho^2}}{c},\theta,\phi)\sigma_0(\theta)}{H^2+\rho^2} \rho d\rho d\phi \tag{16}$$

or

$$w_{\mathrm{r}}(t) = \frac{1}{2}\sqrt{\frac{k}{\pi}} \int_0^{2\pi} \int_0^{\vartheta_a/2} s(t-\frac{2H/\cos\theta}{c},\theta,\phi) \sigma_0(\theta)\frac{\sin\theta}{\cos\theta} d\theta d\phi \tag{17}$$

IV. UWB RADIO FUZE TARGET SIGNAL SIMULATION

Simulation the UWB radio fuze target signal with "(17)",we should know the $s(t,\theta,\phi)$ first.Place two planar dipole antenna in parallel,one is transmitting antenna,the other is receiving antenna,the receiving antenna located at the maximum radiation direction of the transmitting antenna. The transmitting antenna excitation signal as Figure 4., the receiving antenna load 50Ω.The waveform and spectrum of receving antenna shown as Figure 5.

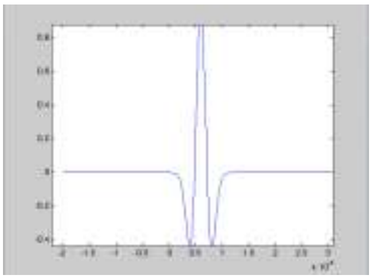

Figure 4.Antenna excitation signal

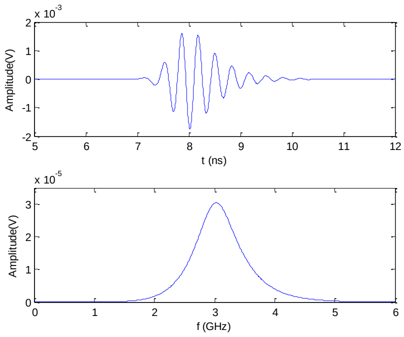

Figure 5.The voltage of the load receiving antenna

In the antenna half power beam width, $\sigma_0(\theta)$ is constant σ_0 ,ignore the antenna radiation at different radiation direction and $F(t,r',\theta',\phi')=1$, "(16)"change to:

$$w_{\mathrm{r}}(t) = \sigma_0\sqrt{k\pi} \int_0^{Htg(\vartheta_a/2)} \frac{s(t-\frac{2\sqrt{H^2+\rho^2}}{c})}{H^2+\rho^2} \rho d\rho d\phi \tag{18}$$

For a fixed level ground, $\sigma_0\sqrt{k\pi}$ is constant.

From“(18)”,simulate with MATLAB,when $\vartheta_{\alpha}=60°$,change the height H,get the UWB radio fuze target signal as shown Figure 6. and Figure 7.：

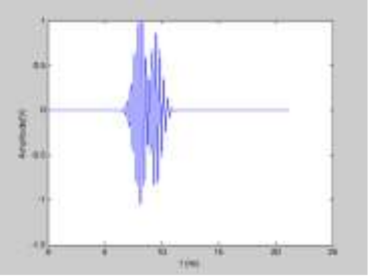

Figure 6.H=1m target signal

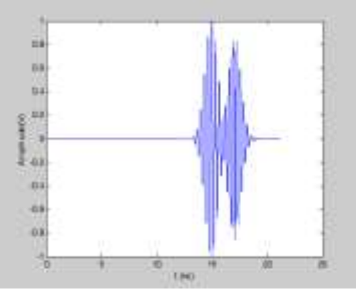

Figure 7. H=2m target signal

V. CONCLUSIONS

The purpose of this study is to get the UWB radio fuze target signal through the triangular dipole antenna.It can be conclude Through modeling of ultra wideband radio fuze target signal, draw the following conclusion:

On the basic study of UWB linear theory and triangular dipole antenna, starting from the effect of multipath UWB signal,establish and simulate the UWB radio fuze target signal model,using integral method for the ground.

The different distance between the fuze antenna and antenna beam irradiation range will cause the broadening effect,the distance from fuze to ground H higher,the broadening effect stronger.

After the actual test, the simulation results are basically consistent with the test results.

REFERENCES

[1] B.Muklas , N S.Rahim ,K.Abdul , S.Norhudah ,G.Kim . “A design of compact ultra wideband coupler for butler matrix”[J]. Wireless Personal Communications,2013(v70,n2): 915-926

[2] Liu Jian-jun,Zhong Shun-shi. “Study on Super-Wideband Antennas for Multi-Band Wireless Communication Systems”[D].School of Communication and Information Engineering Shanghai University,2010.7:17-20..

[3] L.H.Ye, Q.X. Chu “3.5/5.5 GHz Dual Band-notch Ultra-wideband Slot Antenna with Compact Size ”[J]. Electronics Letters 2010(v46 , Issue: 5): 325 – 327..

[4] S.Lin , R N.Cai; G L.Huang,J X.Wang “.A miniature UWB semi-circle mono printed antenna”[J].Progress In Electromagnetic Reserch Letters,2011(v23):157-163

[5] S.Z.Sapuan,A.Kazemipour, Z.M.Jenu. “Direct feed biconical antenna as a reference antenna” [J].2011 IEEE International RF and Microwave Conference (RFM2011)：5-8.

[6] P.L. Carro and J. de Mingo, “Analysis and Synthesis of double-sided parallel-strip transitions,” 2010 IEEE Trans. on Microwave Theory and Techniques, vol. 58, no. 2.

[7] H.Schantz. The art and science of ultrawideband antennas[M].Beijing:Posts and Telecom Press,2012.

[8] A.Idahosa.“A novel compact dual-linear polarized UWB Antenna for VHF/UHF applications”[J].2009 IEEE Antennas and Wireless Propagation Letters,v8,p 145-148.

[9] J.D.Kraus.Antenna:For all applications(Third Editions)[M].Beijing, Publishing House Of Electronics Industry,2011.

[10] Yildirim, S.Bahadir ,A. Bedri A.;R.Gemma;J.Luis. “Integrated Bluetooth and UWB antenna”[J]. IEEE Antennas and Wireless Propagation Letters,2009,v 8,p 149-152.