Investigation of Influence of Season Alternance and Terrain Undulation on Scene Matching Guidance

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***Abstract*—The influence of season and terrain on the performance of the scene matching end guidance is studied, respectively. Seasonal changes would result in the regular transformation of surface vegetation, especially the ratio of water, which could change the electromagnetic characteristics of the ground. Complex permittivity changes regularly according to the liquid water storage per unit, while the quantity of signal attenuation increases with the transmitting frequency. On the other hand, the status of the surface of the earth as well as internal elements of the radar will influence the precision of height measurement, which can bring indirect influence for the image matching. Undulating terrain can also cause changes of the electromagnetic characteristics, which lies in the translation of image points, and there is a close relationship between the position offset and the altitude of the image area.**

Keywords—Seasonal Change; Terrain Undulation; Scene Matching Guidance

I. INTRODUCTION

Precise attack has become an important measure for the seizing of victory of the war as the development of modern military science and technology. How to improve the guiding level of various Precision Guide Weapons (PGW), for example, the intercontinental ballistic missiles, is a hot research topic among many countries of the world. Image matching guidance is one of the valid methods for accurate guiding of missiles which has been widely used.

Terminal guidance of image matching determines current location by comparing real time images got from the radar with that stored in the missile-borne computers, and then modifies the flying route. The vegetation will show regular variation as the seasons change, which will influence the real time imaging of the seeker and then damage the guidance. What's more, the terrain undulation would bring the change of electromagnetic scattering characters, thus influence the precision of measurement of height of the missile as well as the resolution of imaging. To grasp the patterns, we investigated various situation of the ground, including that rises and falls slowly (for example, the plain), that with fairly big fluctuations (hilly areas) and that fluctuates sharply (mountains). The influence on the imaging and guidance of the different kinds of ground is considered.

II. INFLUENCE ON THE IMAGING AND GUIDANCE OF THE CHANGES OF SEASONS

To realize guidance with high precision, the discipline of the scattering features according to the vegetation in spring, summer, autumn and winter has to be studied. Database is required to be built in typical areas to support the precise attack. Since crops such as wheat, rice and sugarcane will show clear difference during their lifespan, the agricultural areas would reflect different signals on the radar. For some grassland, the water content is high in the summer while it is lower in winter, even withers or leaves the soil naked.

The features of the materials that combine the objects on the ground have important influence on the radar echoes, which is mainly determined by the complex dielectric constant. Generally speaking, the bigger the complex dielectric constant becomes, the stronger that it reflects the radar waves and the weaker that it can be penetrated.

TABLE I. Changes of the echo amplitudes of the grassland with the season alternance (Band Ka)

Month	3	4	5	6	7	8	9	10
Echo(dB)	-17.5	-15.5	-11	-10	-10.5	-11.5	-12	-12.5

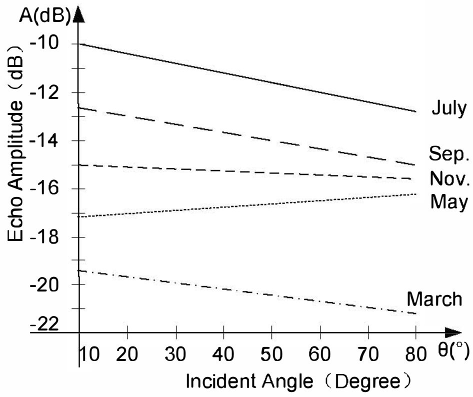

Fig. 1. Changes of the echo amplitude of the grassland with the season alternance (Band Ka)

The complex dielectric constant consists of two parts: the real part that stands for the dielectric constant and the imaginary part that indicates the loss factor. The loss factor means the attenuation during the propagation of the electromagnetic waves, which is relative with the conductive

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rate of certain elements. The complex dielectric constant shows linear variation according to the content of liquid water in unit volume. The low content of water will lead to high penetrating rate of radar waves and little reflection, and vice versa. The dynamic range of the complex dielectric constant of water is 20～80 within the whole microwave frequency band, while that of most natural matter (Vegetation, soil, rock and snow, etc.) is only 3～8. Here the distinct effect of water content on radar echo waves can be inferred.

Analysis of venerations and soil humidity is very important in the interpretations of radar images. On the other hand, the attenuation rate of microwave is the function of the conductive and radiation rate of certain material. In general, the loss increases with frequency while the penetration rate decreases. This influences the echoes. In the high frequency band, the echoes are produced mainly by the upper parts of the vegetations due to the low rate of penetration, and naturally the lower parts in lower frequency bands. Remote sensing echo data of Band Ka for some grassland in different seasons with the same measurement system as well as the same parameters is showed in Table 1. The echo amplitudes of the grassland in Band Ka of different months are presented in Figure 1.

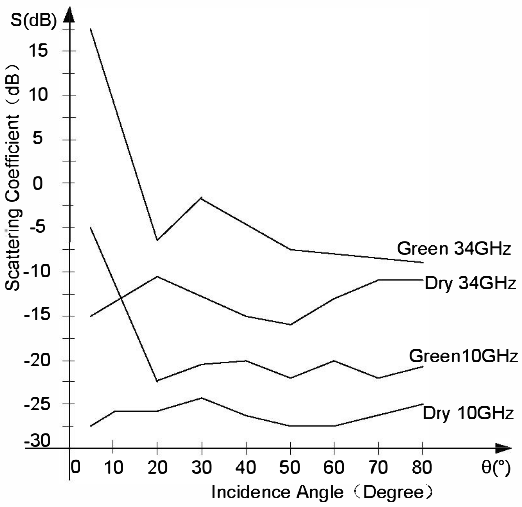

Fig. 2. The scattering coefficients of the grassland in different seasons

The influence of water content on scattering is showed in Fig. 2, from which it can be found that the scattering coefficient usually increase with the water contents. The dotted lines and the continuous lines stand for the testing results in summer and winter respectively. As for the two lines of the same season, the larger one in value of coefficient belongs to radar frequency 34 GHz (wavelength 8.8 mm), and the smaller on belongs to 10 GHz (wavelength 30 mm).

III. THE ERROR OF HEIGHT MEASUREMENT

A radar altimeter is a kind of ranging radar whose target is the ground, mainly including frequency modulation (FM) and pulse mode. Since it is easy for the transmitting signals to leak into the receiver, FM altimeter is usually used in measurement of short distance. On the other hand, long distance measurement usually use pulse altimeter with pulses not too narrow to generate and distinguish.

The most important factor that can influence the performance of the radar altimeter is the harshness of the ground. Echoes from the target are mixture of the surface scattering and the inside reflection.

The echo of the vertical incidence wave is the most intense for a fairly large plane (compares with the wavelength). The scattering would not attenuate even deviates the vertical direction to a big extent for a small plane. The reflection pattern remains nearly isotropy if the size of the plane is less than the wavelength.

The influence of attenuation is similar to that of low SNR (signal-noise ratio) in the measurement of a pulse altimeter. For certain area with uniformity gurgitation, the amplitude of the echo pulse appears to be Rayleigh distribution.

According to the principle of altimeter, the errors come from the situation of the ground together with internal factors of the radar. The latter includes Doppler frequency shifting, shaking of the pulse front edge, stability of the criterion frequency, thermal noise and the temperature coefficient of the delay line.

IV. THE INFLUENCE OF TERRAIN UNDULATION ON THE IMAGING

A. *Real time radar imaging*

The real time radar images are achieved from the low-altitude (usually several kilometers) aircraft. To eliminate the influence of short distance compression on the inclined direction image, horizontal distance imaging mode is used. The geometry forms of the real time image and the reference one are concordant, when the domination factor that would influence the matching is the difference of their radiation features. When there exists height undulation, the figure building modes would differentia largely enough to influence the precision of the matching and guidance.

The SAR (Synthetic Aperture Radar) imaging is a kind of range imaging. When there is undulation on the ground, the pixel shift in the direction of range will be,

$$dy = -h\cos\theta / r \qquad (1)$$

Where, h is the height difference to the reference plane, and r is the pixel resolution.

When the amount of the up and down of the ground is fairly big (more than 50 m), the accurate imaging formulas need to be built and the geometry calibration be carried out. It is better to consider the DEM (Digital Elevation Model) data to eliminate the image distortion caused by the terrain undulation.

B. *The computation of the influence of the terrain undulation*

The terrain undulation will directly result in the change of calculation of the inclined range. The echo signal of the undulation point will corresponds to the point in the horizontal point of the same inclined range which causes the geometry change of the image, as showed in Fig. 3.

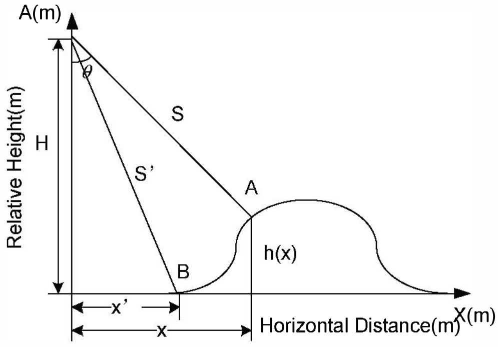

Fig. 3. Sketch of the terrain undulation

To study the influence of the terrain undulation on the image matching performance of the radar, we set the height variation meet the 2-D Gauss distribution function,

$$f(x,y)=\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-\mu)^2+(y-\mu)^2}{2\sigma^2}} \quad (2)$$

Where, μ is the mean value, σ^2 is the variance and $f(x,y)$ is the height. To choose the typical values for (μ,σ) = (300,150), (1200,600), and (2600,1300), the relative $f(x,y)$ can stand for plain, hill and mountain.

Suppose the size of the radar image is fixed, and the sampling rate changes with the imaging height H according to certain proportion. The image resolution, $R=H/r$. The deviation amount of the imaging point

$$\Delta x_1=\Delta x/R \quad (3)$$

$$K=x/H=tg\theta \quad (4)$$

$$p=h(x)/H \quad (5)$$

The calibration based on the vertical projection,

$$x^{'}=\sqrt{(H-h(x))^2+x^2-H^2}=H\sqrt{K^2-(2p-p^2)} \quad (6)$$

The deviation amount of the resolution element in the real time image relative to the reference image is,

$$\Delta x=x-x^{'}=H(K-\sqrt{K^2-(2p-p^2)}) \quad (7)$$

It can be further transformed to,

$$\Delta x=r(K-\sqrt{K^2-(2p-p^2)})=\frac{r(2p-p^2)}{K+\sqrt{K^2-(2p-p^2)}} \quad (8)$$

A set of typical values are as followings,

$r=H/R$,

$H=4000$ m, $R=5$ m,

$K=x/H$,

$p=h(x)/H=f(x,y)/H$.

Where, $f(x,y)$ is the above mentioned Gauss function.

Thus, the influence of the terrain undulation on the imaging can be deduced as the translation of image points. The follow-up processing can be carried out on the image to get the distortion figures and then complete the image matching.

It could be found from the above formula that the deviation of image points relates to the imaging height and the extent of terrain undulation. The ratio of the up and down on the ground to the imaging height usually meet the condition of $p<0.5$, then if H increases, p will decrease, and the deviation of the image point Δx_1 will decrease too. If the up and down on the ground $h(x)$ increases, p and the deviation of the image point will increase, too.

V. CONCLUSIONS

The changes of ground vegetations brought by the change of season alternance together with the height change of the terrain undulance would influence the real time imaging of the guided missiles. The main form of the influence is the amplitude decrease by attenuation and the signal distortion by the scattering. The situation of the ground surface and the internal technical indexes of the radar would bring disadvantage to the scene matching. Furthermore, many other factors such as the matching algorithms, condition of the weather, the flying speed, features of the radome and the error of angle measurement would influence the matching and guidance performance, which require investigation and compensation to benefit the precise attack.

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