NEAR-FIELD OF GROUND BACKSCATTERING
USING A NORMAL INCIDENT RECEIVING ANTENNA

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1. Introduction
In remote sensing applications, dimension of coverage area on the ground with a normal incident receiving antenna is varying with the platform altitude of the sensor. Historically, the size of the coverage area has not been considered to calculate the far field condition due to the reason that the phases of the return wave from the area are not coherent. In this abstract we will show that although the phases are absolutely random, the near field effect still exist in a surface scattering case.

2. Geometrical relations
Figure 1 shows the geometrical configuration of the problem, where the dimension of the ground coverage area is

\[ D = 2h \tan\left(\frac{\theta_{0.5}}{2}\right) \]  

where \( \theta_{0.5} \) is the half power beam width of the receiving antenna. From the far field condition,

\[ r > \frac{2D^2}{\lambda} \]  

we obtain

\[ r = \frac{8h^2}{\lambda} \tan^2\left(\frac{\theta_{0.5}}{2}\right) \]

This means that the far field condition will never be fulfilled since \( r \) is increasing quadratically when \( h \) is changing linearly. Another important thing formula (3) tells us is that the receiving antenna is located in different near field positions while \( h \) is different. In other words, the larger platform altitude is, the closer it is electrically to the ground due to the far field condition.

3. Discrete surface scattering model
To further analysis the near-field effect of the ground backscattering, we now consider a discrete surface scattering model. We use half wave length spaced and
randomly phased small circular discs to represent the ground surface. The purpose of this model is not to model the absolute backscattering coefficients of the ground surface, but to represent the general backscattering property of a surface in order to show the relative variations of the normalized backscattering coefficients for different platform altitudes.

We now consider the field of a z-direction oriented small disc,

\[ E = E' e^{j \frac{2\pi}{k \sin \theta} J_1(ka \sin \theta) \frac{e^{-ikr}}{2\pi}} \left( \hat{\theta} \cos \phi - \hat{\phi} \sin \phi \cos \theta \right) \]  \hspace{1cm} (4)

where \( J_1 \) is the first order Bessel function. Since we now consider only the field in \( \hat{x} \) direction, (4) becomes to,

\[ E_z = E' \hat{z} = E' \frac{2\pi}{k \sin \theta} J_1(ka \sin \theta) \frac{e^{-ikr}}{2\pi} \cos \theta \]  \hspace{1cm} (5)

Let \( \alpha \) (radius of the small disc) be \( \lambda/8 \), (5) becomes,

\[ E_z = E' \frac{\pi}{4 \sin \theta} J_1 \left( \frac{\pi}{4 \sin \theta} \right) \frac{e^{-ikr}}{kr} \cos \theta \]

\[ = \frac{E' \pi^2 \cos \theta}{16kr} \frac{1}{\sin \theta} J_1 \left( \frac{\pi}{4 \sin \theta} \right) \]  \hspace{1cm} (6)

As shown in Figure 2, composed field at \( h \) from all small disc is,

\[ E_z = \sum_{i=1}^{n} E' \frac{\pi^2 \cos \theta_i}{16kr_i} \frac{J_1 \left( \frac{\pi}{4 \sin \theta_i} \right)}{\sin \theta_i} \]  \hspace{1cm} (7)

where \( E_i \) is the complex excitation coefficient of disc number \( i \); \( n \) is the total number of discs included in the coverage area calculated by \( h \) and \( \theta_i \); and \( \theta_i \) is the incident angle of disc number \( i \) from the platform.

4. Test Examples
Using the above surface scattering model, we have calculated several test examples. Figure 3-4 shown the normalized backscattering coefficient variation
when platform altitude is increasing. The discs are excited with uniform and random phase excitations respectively. Figure 5 shown the normalized backscattering coefficients when the size of the coverage area is fixed (the far field situation), where we can see that while the far field condition is fulfilled, $\sigma_n$ will then converge to a constant value.

4. Discussions
The periodical variation of the backscattering coefficient versus the platform altitude reflects the near-field effect of the ground surfaces. The anticipation of a non-coherent phase one usually taken is not true. The near field effect can be observed even in a situation where random phase excitation is used.

From further test examples, we have also discovered that the period of the variation is closely related to the half power beam width of the receiving antenna of the sensor. Therefore one may be able to predict where the platform is located in the period and will be able to give reference calibration value to increase the sensors measurement accuracy. This will however discussed in a separate paper when the work is totally finished.

References:

![Figure 3, Uniform phase excitations](image-url)
Figure 4, Random phase excitation

Figure 5, Fixed coverage area