The Electromagnetic Wave Scattering from Building Surfaces for the Mobile Propagation Modeling

Mobile Communication Research Group
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Background

The future mobile communication system development requires more detailed propagation model.

Conventionally, ray tracing tool is used to model the urban environment (eg. building, vegetation).

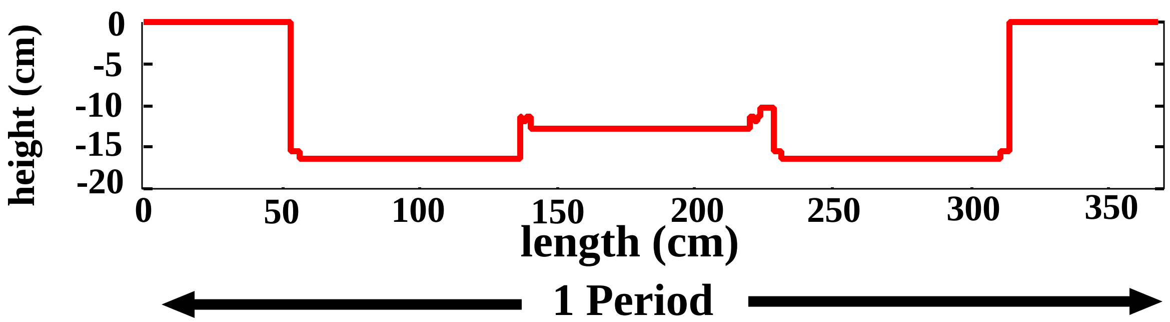
However, the roughness of the surface has been neglected or considered only as the average.

Objective

- To estimate the electric field scattering from building rough surface by using numerical method.
- To evaluate the fluctuation and its autocorrelation of the field strength due to change of the specular reflection point on the surface.
- To study the effect on the incident angle and frequency

The Model of Building Rough Surface

The INCOCSAT Building - TIT



Metodology

The total electric fields satisfies the following scalar Helmholtz equation.

$$\nabla^2 E_z + k^2 E_z = j\omega\mu J_z^{tot} \quad \textbf{(1)}$$

From eq. 1, the following Kirchoff-Huygens principle is derived,

$$E_z(\rho) = j\omega\mu \int_S J_z^{inc}(\rho')G(\rho,\rho')dS + j\omega\mu \oint_{\partial S}(\nabla' E_z(\rho)G(\rho,\rho') - \nabla' G(\rho,\rho')E_z(\rho)) \cdot \hat{n} dl \quad \textbf{(2)}$$

where,

J_z **is the induced surface current for the scattered field.**
J_z^{inc} **is the primary current for the incident field.**
∂S **is the surface of the scatterer.**
S **is the domain of source.**

Method of Moment

Using the PEC boundary condition on the surface as,

$$E_z^{inc}(\rho) + E_z^{scat}(\rho) = 0, \qquad \rho \in \partial S \qquad \textbf{(3)}$$

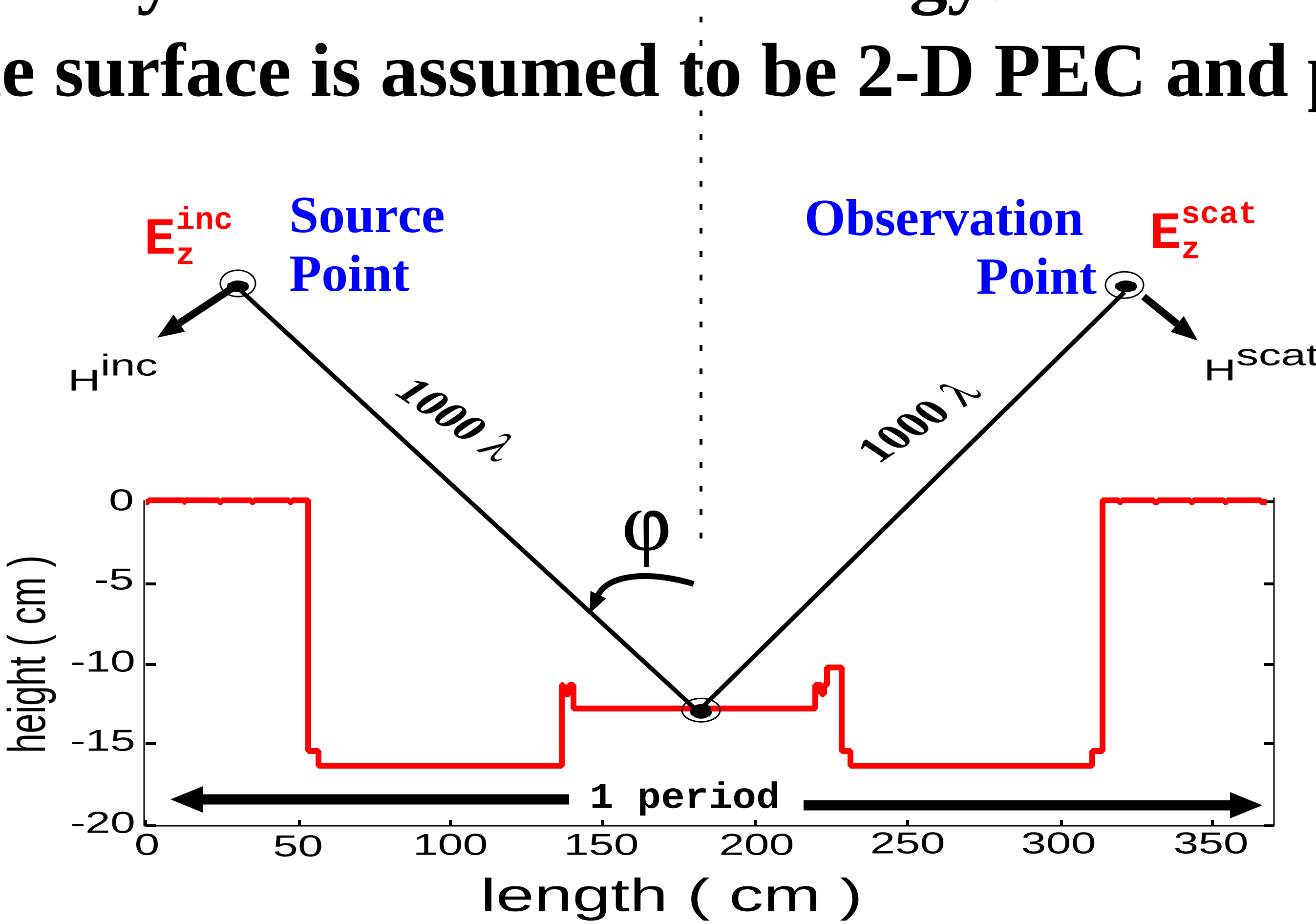
the following Electric Field Integral Equation (EFIE) is obtained.

$$E_z^{inc}(\rho) = -j\omega\mu \oint_{\partial S} J_z^{scat}(\rho')G(\rho,\rho')dl \qquad \textbf{(4)}$$

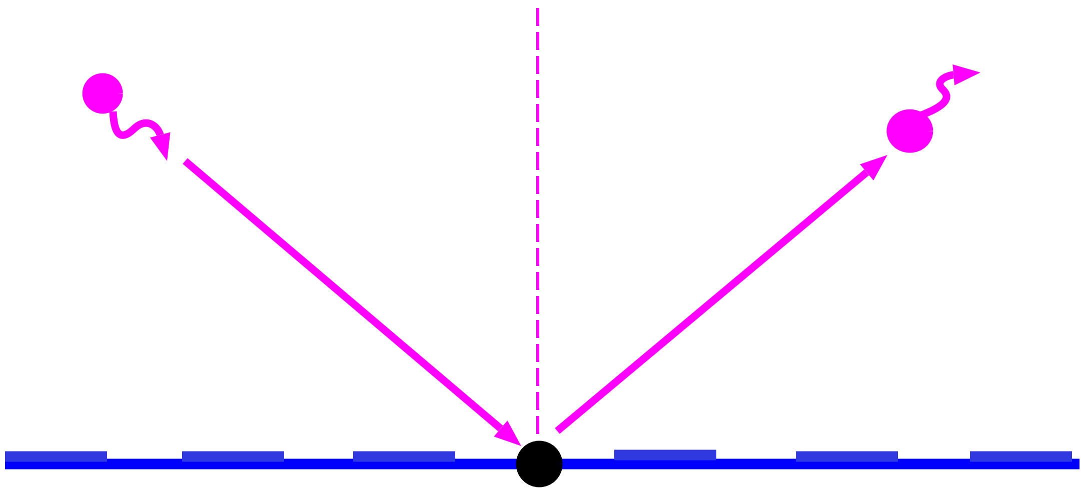
The EFIE is discretized into a set of a finite number of unknowns by pulse basis, point maching method.

Simulation of the Rough Surface

- The profile of surface is taken from a building in Tokyo Institute of Technology.
- The surface is assumed to be 2-D PEC and periodic.

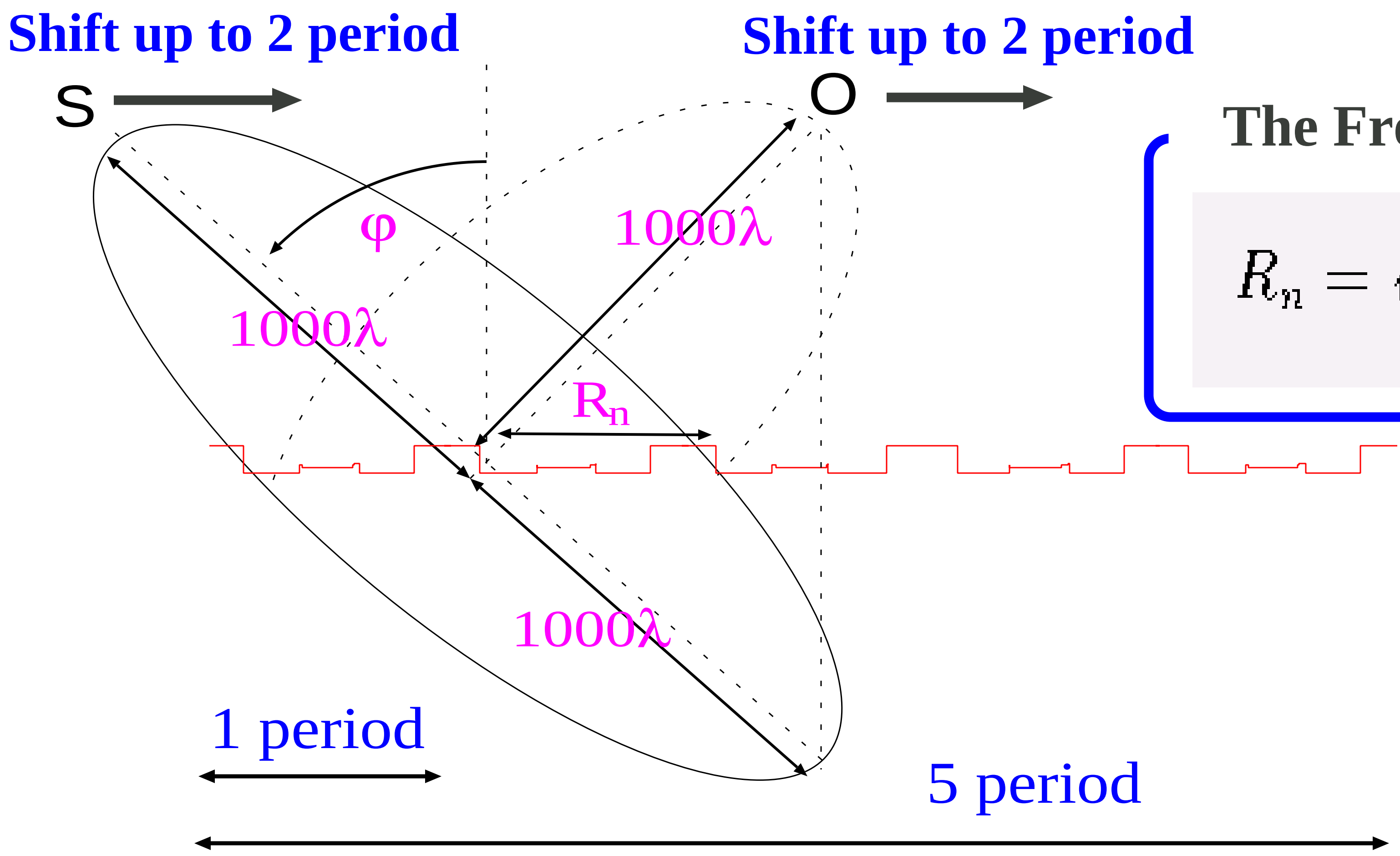


- **The variation of incident angle are 20^o, 45^o, and 60^o.**



- **The variation of incident frequency are 1 GHz, 3 GHz and 6 GHz (i.e. wavelength is 5cm, 10 cm, and 30 cm).**

- **The length of surface is bigger than the third Fresnel zone.**
- **The source and observation point are simultaneously shifted up to 2 period along the wall pattern to get fading.**



The Fresnel Zone

$$R_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

Statistical Properties

The fluctuation of the field strength is evaluated by the cumulative distribution and the autocorrelation.

- **The PDF of Rician Distribution**

$$p_R(r) = \frac{r}{\sigma^2} e^{-(r^2+s^2)/2\sigma^2} I_o\left(\frac{rs}{\sigma^2}\right), \qquad r \geq 0$$

where,

I_o is modified Bessel function of the first kind and zeroth order.

s is the peak amplitude of the constant signal.

σ^2 is the average power of Rayleigh component.

- **The Rician factor (K) can be used for characterization of Rician distribution.**

$$K = \frac{s^2}{2\sigma^2}$$

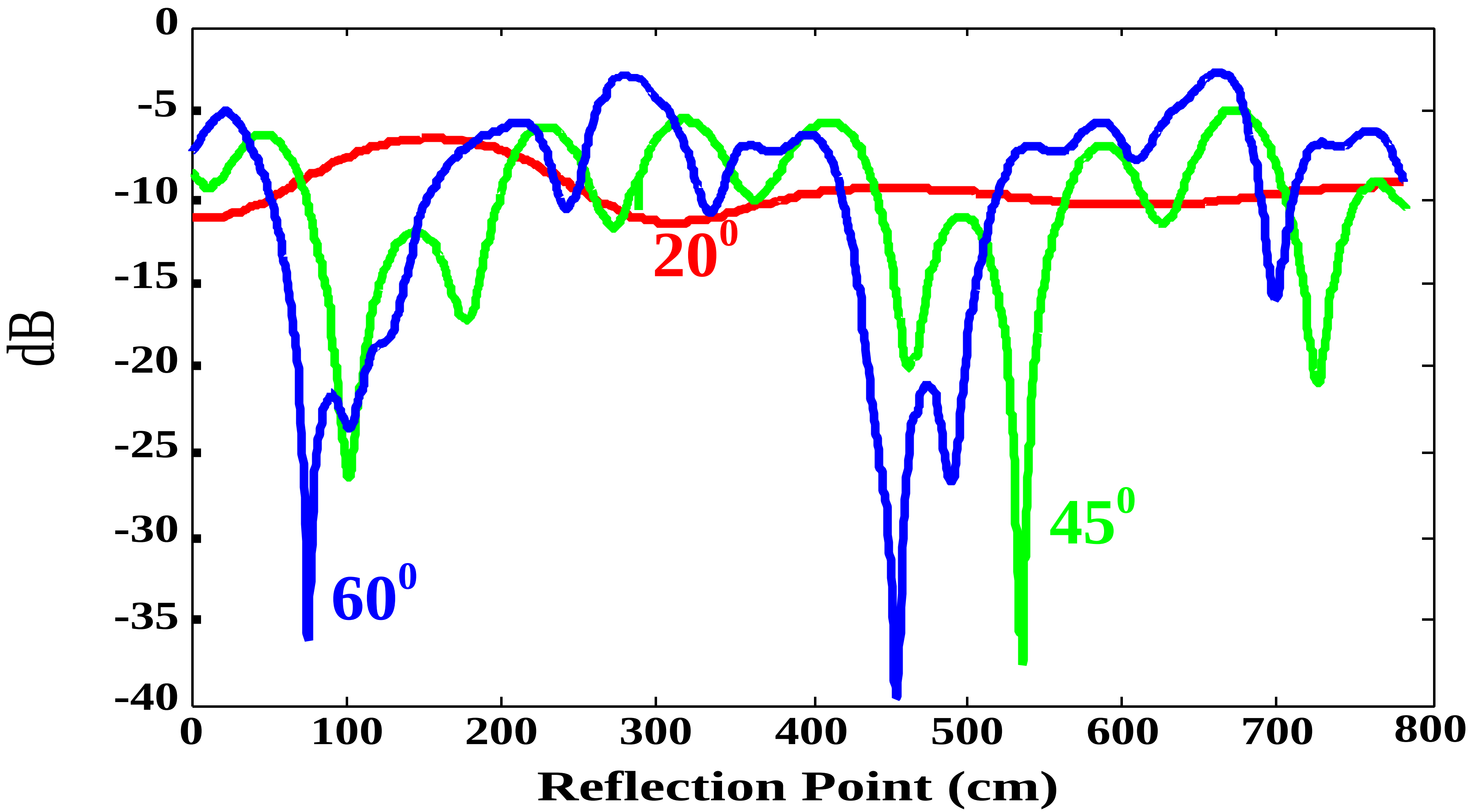
- **The Autocorrelation Function**

$$\phi(k) = \frac{1}{N-k+1} \sum_{i=0}^{N-k} x^*(i)x(i+k)$$

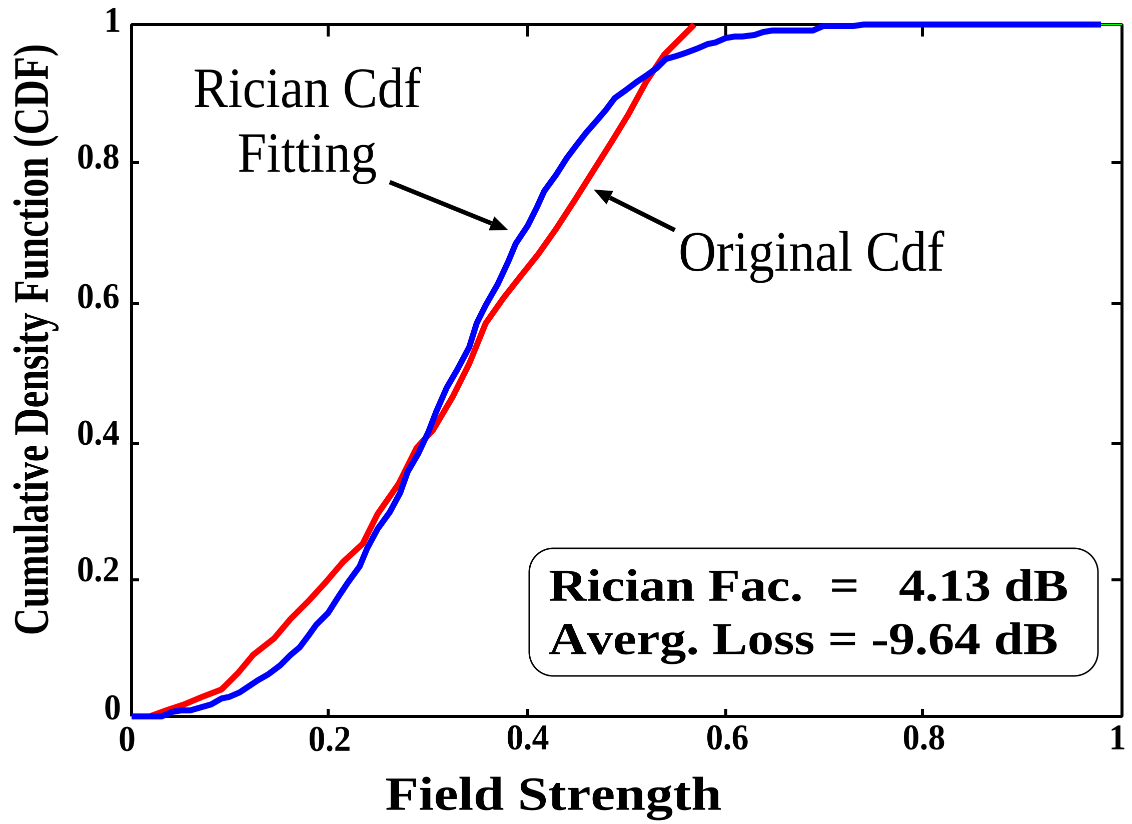
where, x(i) is the i-th signal strength.
k is the index of shifting for reflection point.

The Result of Simulation

The Scattered Field Strength with frequency of 3 GHz for 20^0, 45^0 and 60^0 incidence

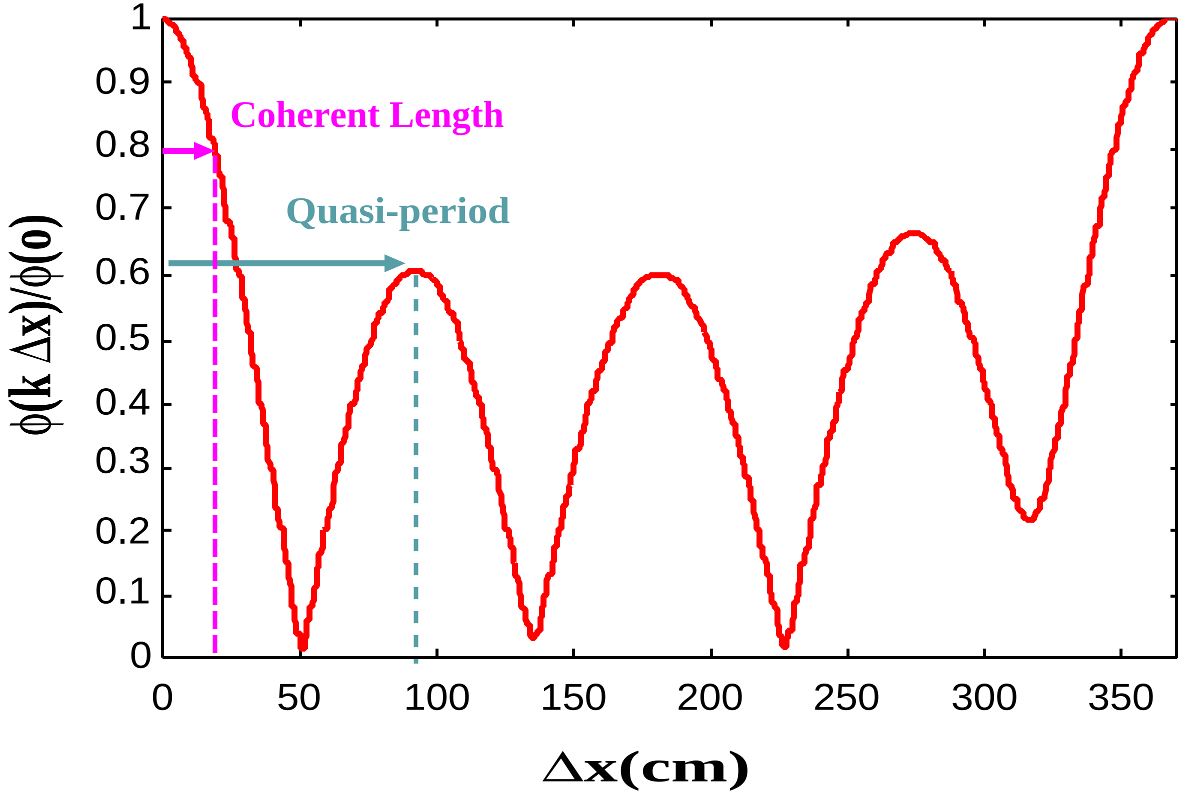


Cumulative Distribution of Signal Strength for 45^0 incidence



The PDF of specular reflection from the surface of the building can be well modeled by Rician distribution.

The Autocorrelation of the scattered field for 45^0 incidence



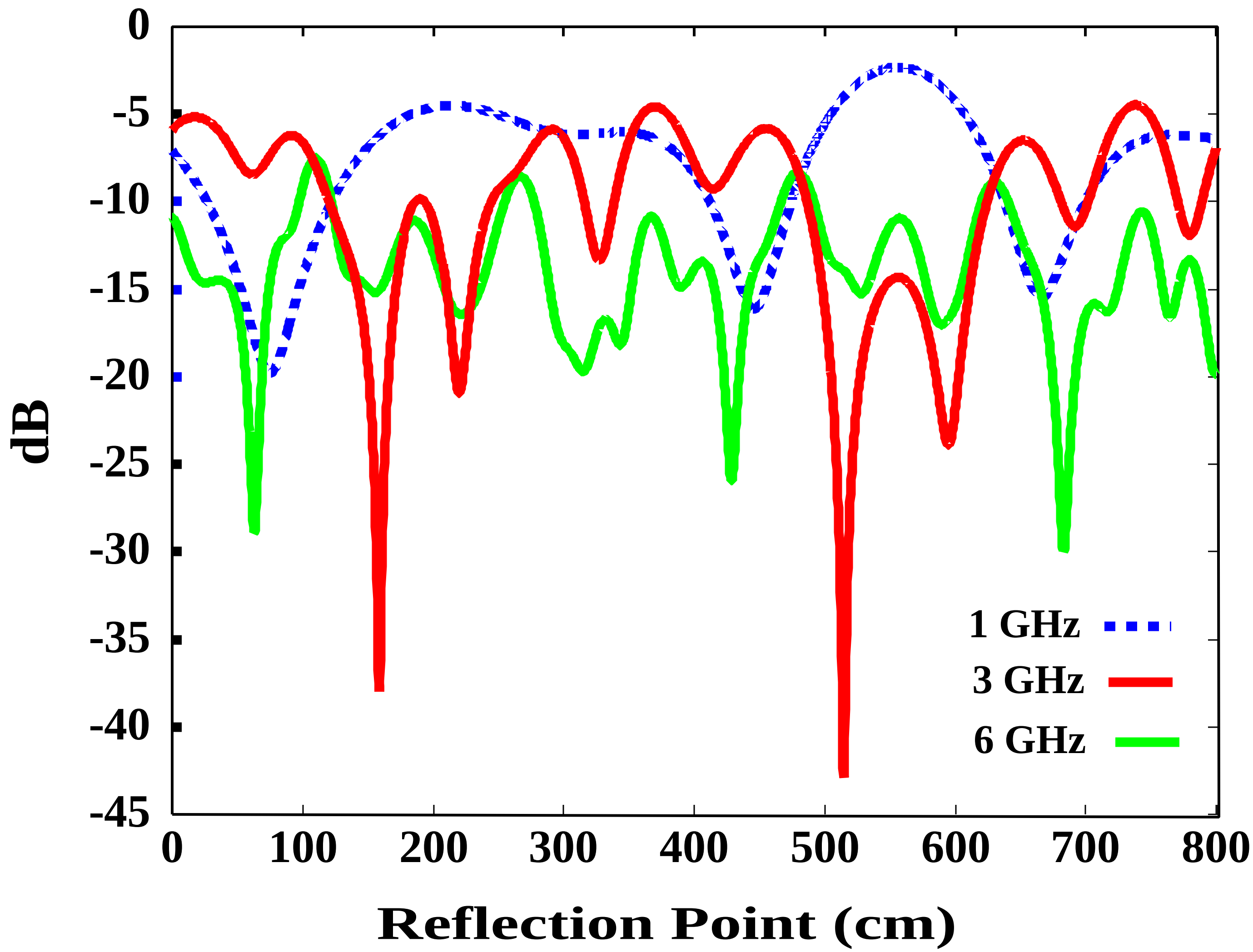
The fluctuation of the field strength is found to be quasi-periodic with period of about 90 cm.

Comparing Rician parameter and Average Loss for The scattered field strength with 3 GHz Frequency

No	Angle	Rician Fac.	Averg. Loss
1.	20	9.23 dB	- 9.48 dB
2.	45	4.13 dB	- 9.64 dB
3.	60	1.57 dB	-10.23 dB

It is noted if the field strength are more fluctuated then the Rician factor becomes smaller.

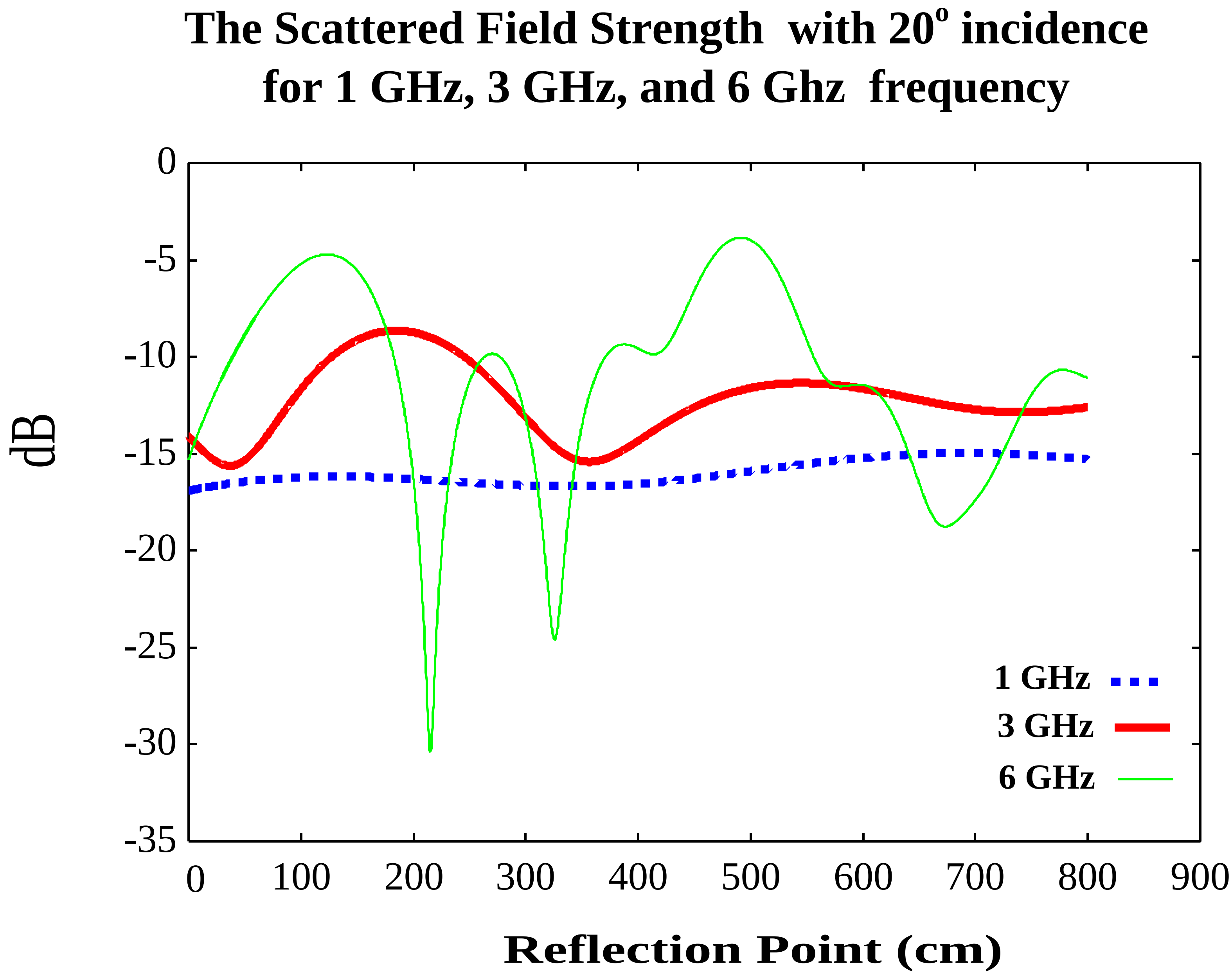
The Scattered Field Strength with 45^o incidence for 1 GHz, 3 GHz, and 6 Ghz frequency



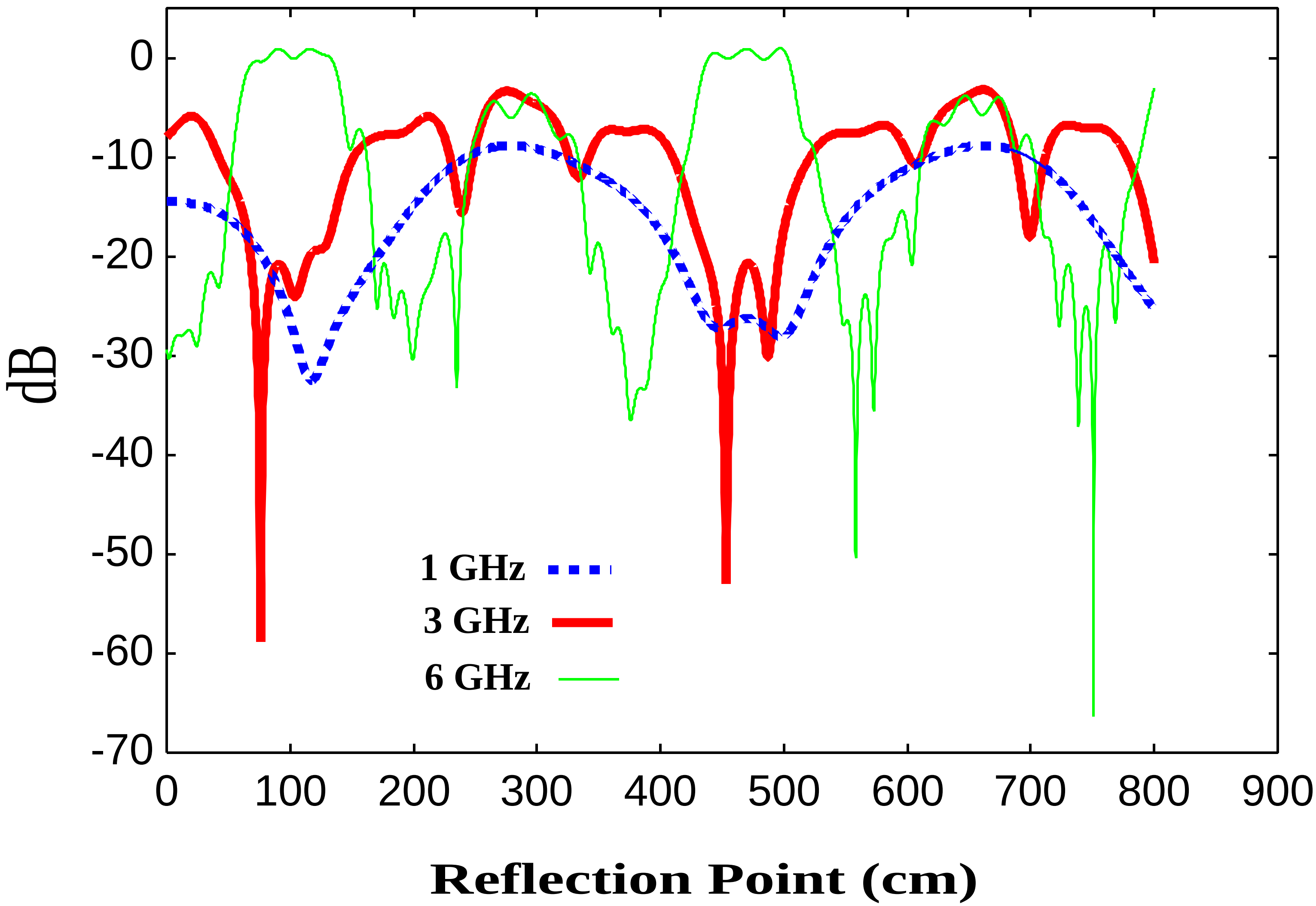
Comparing Rician parameter and Average Loss for The scattered field strength with 45^{o} incidence

No	Frequency	Rician Fac.	Averg. Loss
1.	1 GHz	4.40 dB	- 8.14 dB
2.	3 GHz	4.13 dB	- 9.64 dB
3.	6 GHz	3.75 dB	-14.11 dB

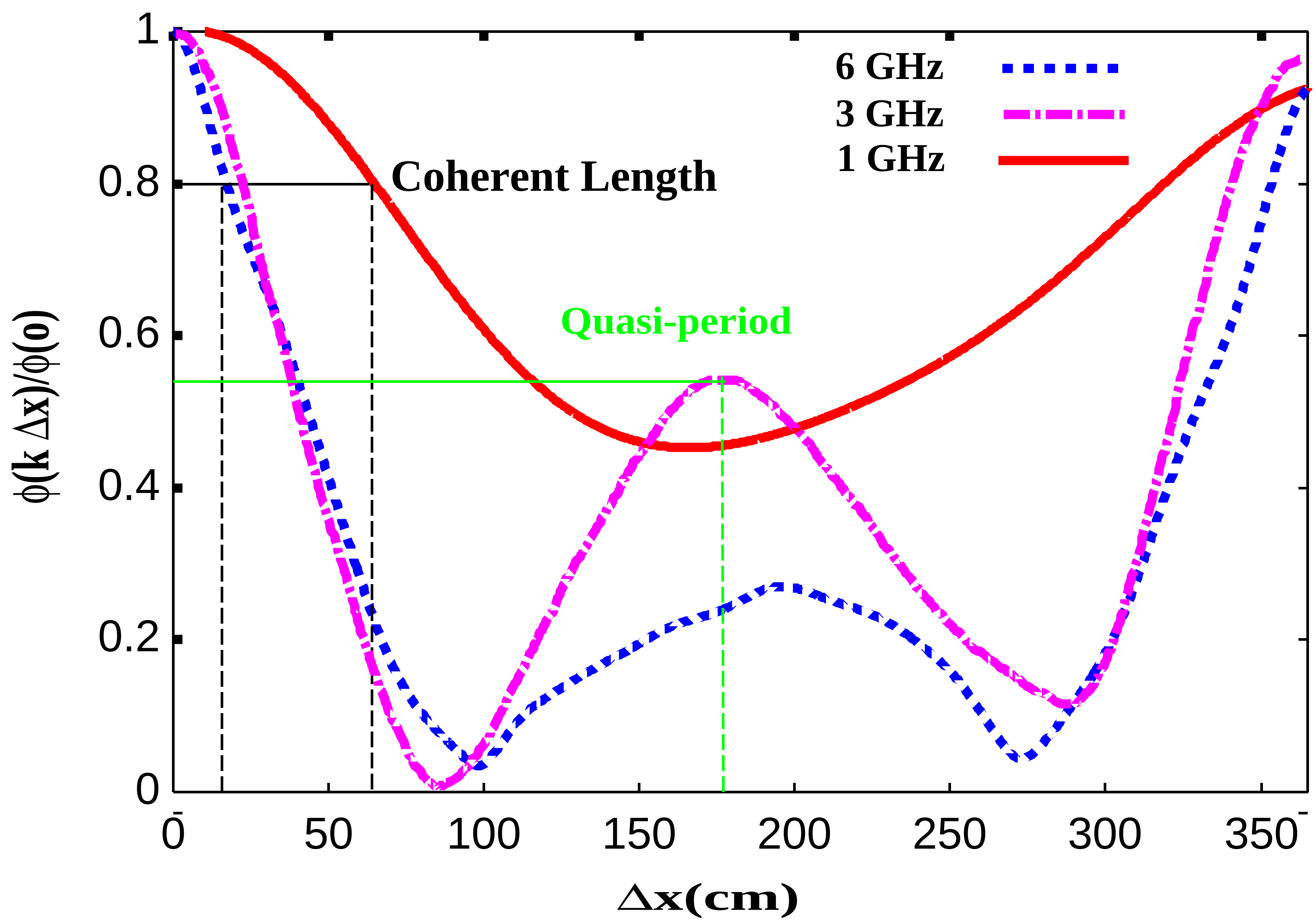
It is noted if the field strength are more fluctuated then the Rician factor becomes smaller.


The Scattered Field Strength with 20° incidence
for 1 GHz, 3 GHz, and 6 Ghz frequency
dB
0
-5
-10
-15
-20
-25
-30
-35
0
100
200
300
400
500
600
700
800
900
Reflection Point (cm)
1 GHz
3 GHz
6 GHz

The Scattered Field Strength with 60^o incidence for 1 GHz, 3 GHz, and 6 Ghz frequency



The Auto Correlation of Signal Strength with 60^{o} incidence for 1 GHz, 3GHz and 6 GHz frequency



Conclusion

- **The numerical estimation of the scattered field fluctuation from 2 dimensional model PEC Rough surface of the building had been done by using method of moments (MOM).**
- **The PDF of specular reflection from the surface of the building can be well modeled by Rician distribution.**
- **The result of autocorrelation suggests the quasi-periodicity of the scattering.**
- **The field strength for each 60^{o} incident angle and 6 GHz frequency are more fluctuated than the others.**

Future Works

- The Method of Moment is good for the small surface but it is time consuming for a larger surface. In this case, it is suggested to use some other fast method.

- 3-dimensional model should be applied with realistic problem.