Mobile Fading Channel

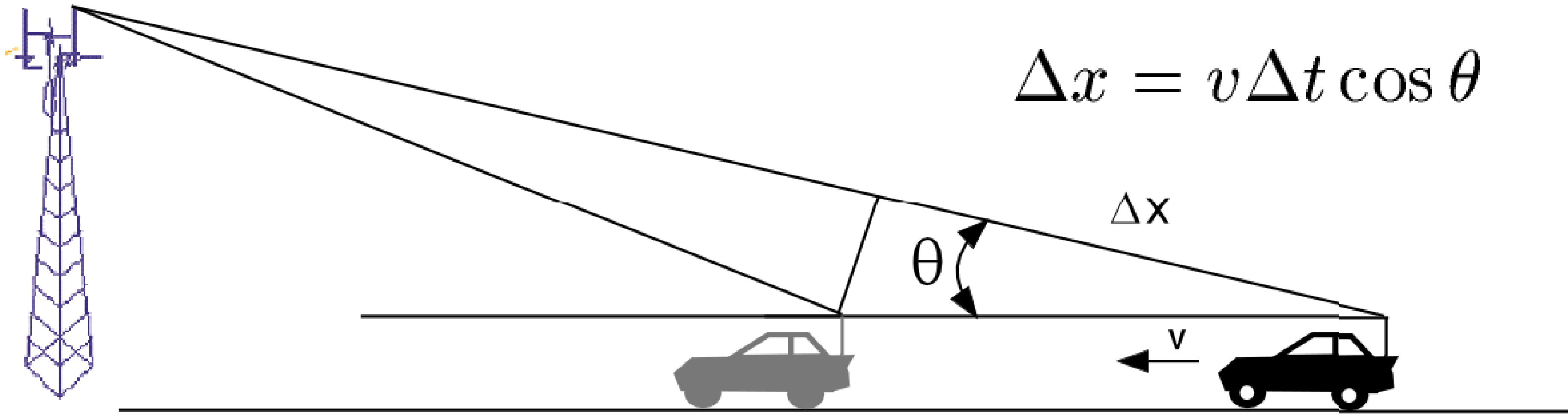
Fading Due to Mobile Subscriber Motion

Silicon DSP Corporation

Reference

Chapter 1

William C. Jakes, Editor (February 1, 1975). *Microwave Mobile Communications*. New York: John Wiley & Sons Inc. ISBN 0-471-43720-4.



$$\Delta x = v\Delta t\cos\theta$$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}v\Delta t\cos\theta$$

$$\frac{\Delta\phi}{\Delta t} = \frac{2\pi}{\lambda}v\cos\theta$$

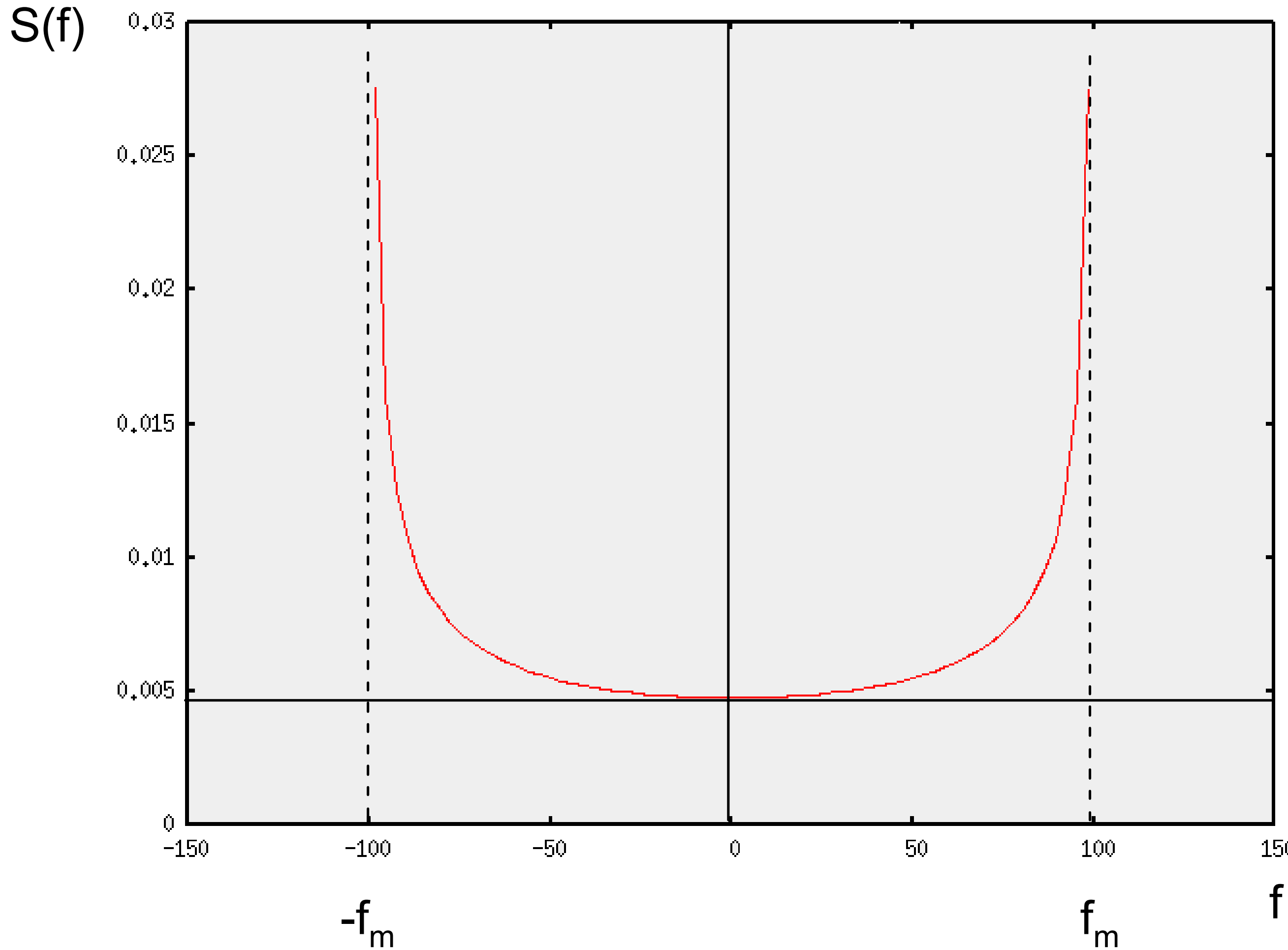
$$f = \frac{1}{2\pi}\frac{d\phi}{dt}$$

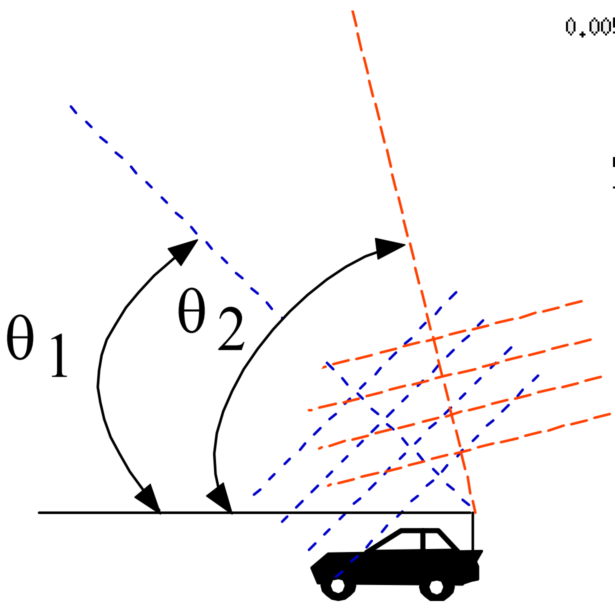
$$f_m = \frac{v}{\lambda}$$

$$f_d = \frac{1}{2\pi}\frac{d\phi}{dt} = \frac{v}{\lambda}\cos\theta$$

$$f_d = \frac{v f_c}{c}\cos\theta$$

$$p(\theta) = \frac{1}{2\pi}$$





$$S(f) = K\frac{1}{\pi f_m \sqrt{1 - \left(\frac{f - f_c}{f_m}\right)^2}}$$

Derivation of Power Spectral Density

$$f(\theta) = f_m \cos\theta + f_c$$

$$f_m = \frac{v}{\lambda}$$

$$f(\theta) = f(-\theta)$$

Denote by $p(\theta)d\theta$ the fraction of the total incomming power within $d\theta$

Antenna power gain $G(\theta)$

Differential variation of received power with angle is $bG(\theta)p(\theta)d\theta$

Equate to the differential variation of received power with frequency.

$$S(f)|df| = b[p(\theta)G(\theta) + p(-\theta)G(-\theta)]|d\theta|$$

$$|df| = f_m|-\sin\theta d\theta| = \sqrt{f_m^2 - (f - f_c)^2}|d\theta|$$

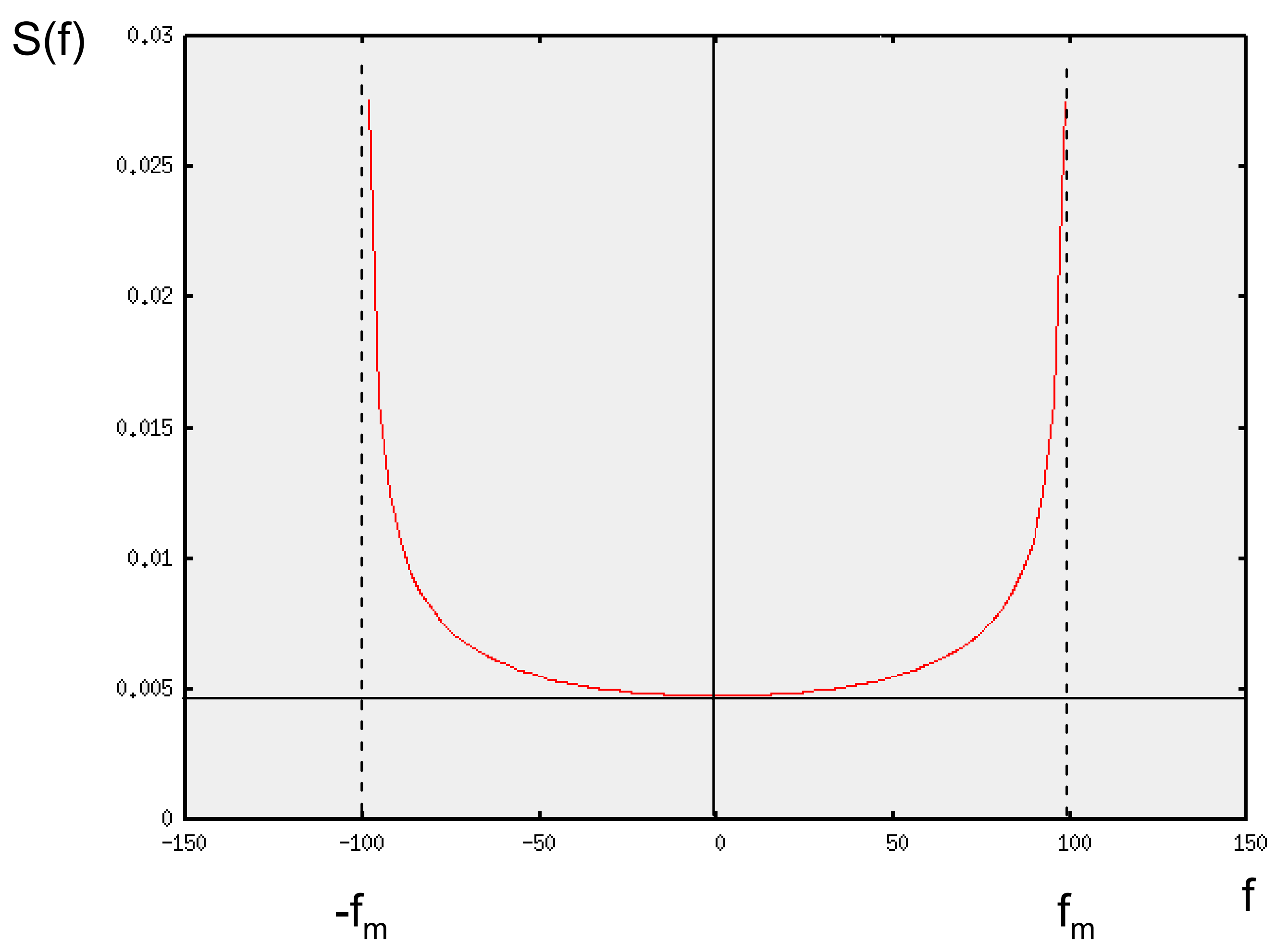
$$S(f) = \frac{b}{\sqrt{f_m^2 - (f - f_c)^2}}[p(\theta)G(\theta) + p(-\theta)G(-\theta)]$$

$$G(\theta) = 1.5$$

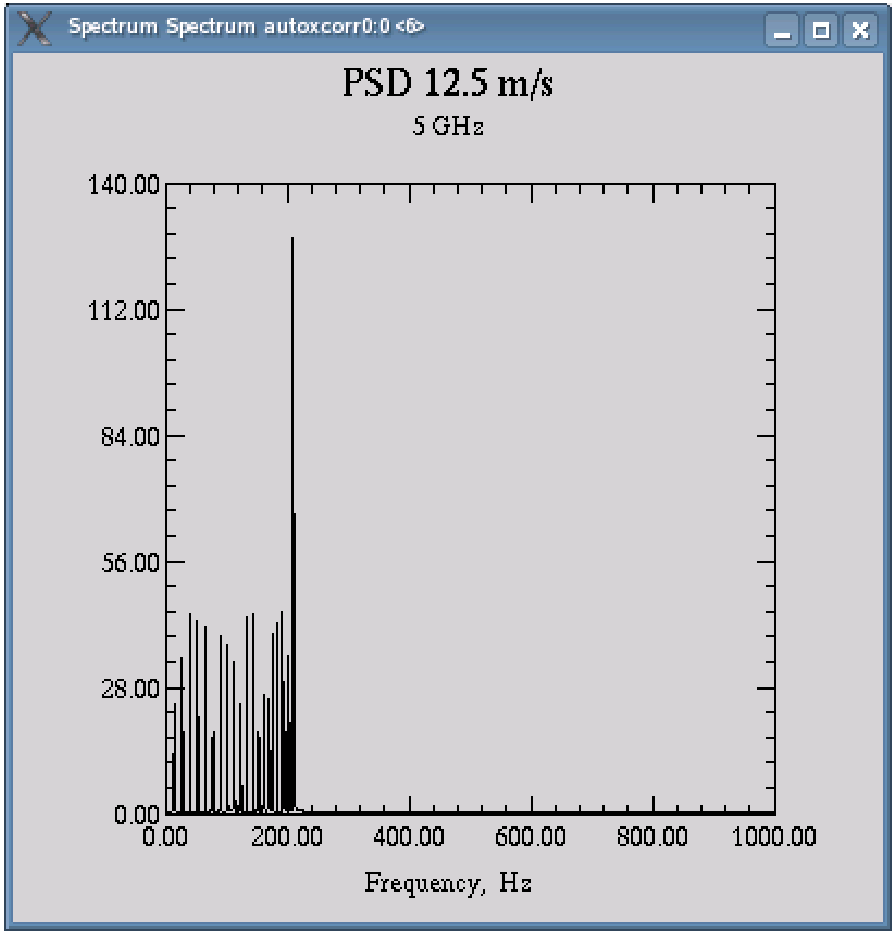
Vertical Antenna λ/4

$$p(\theta) = \frac{1}{2\pi}$$

$$S(f) = K \frac{1}{\pi f_m \sqrt{1 - \left(\frac{f - f_c}{f_m}\right)^2}}$$



$$S(f) = K \frac{1}{\pi f_m \sqrt{1 - \left(\frac{f - f_c}{f_m}\right)^2}}$$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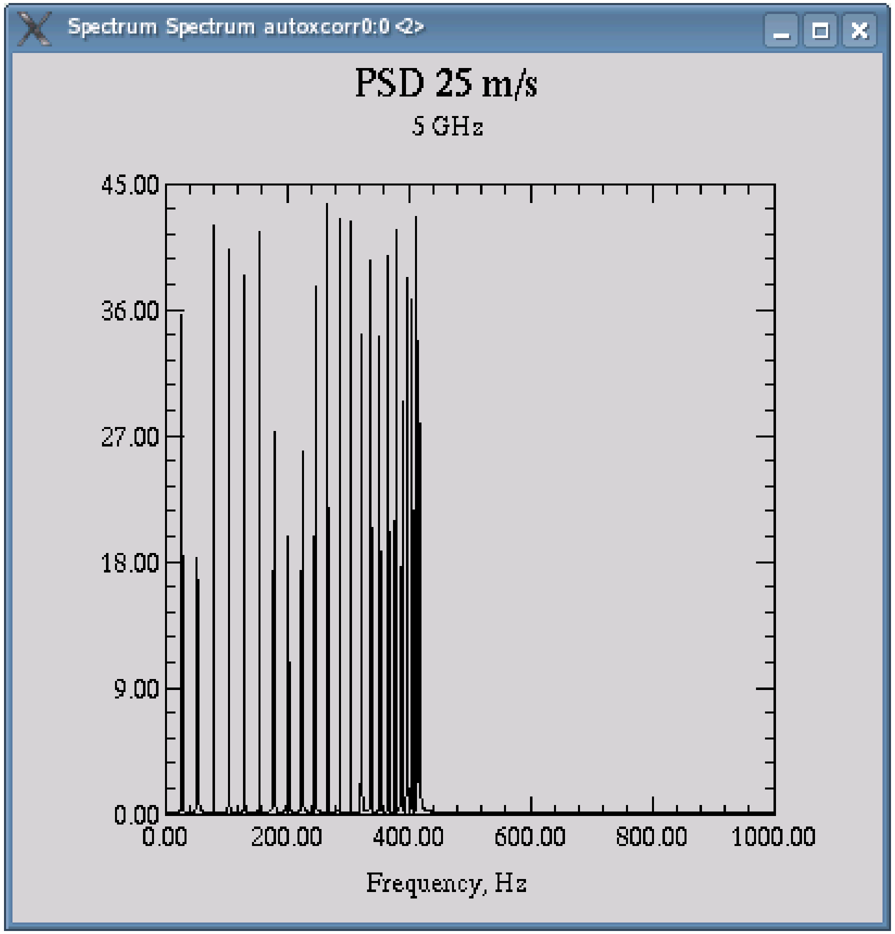
PSD 12.5 m/s
5 GHz
140.00
112.00
84.00
56.00
28.00
0.00
0.00
200.00
400.00
600.00
800.00
1000.00
Frequency, Hz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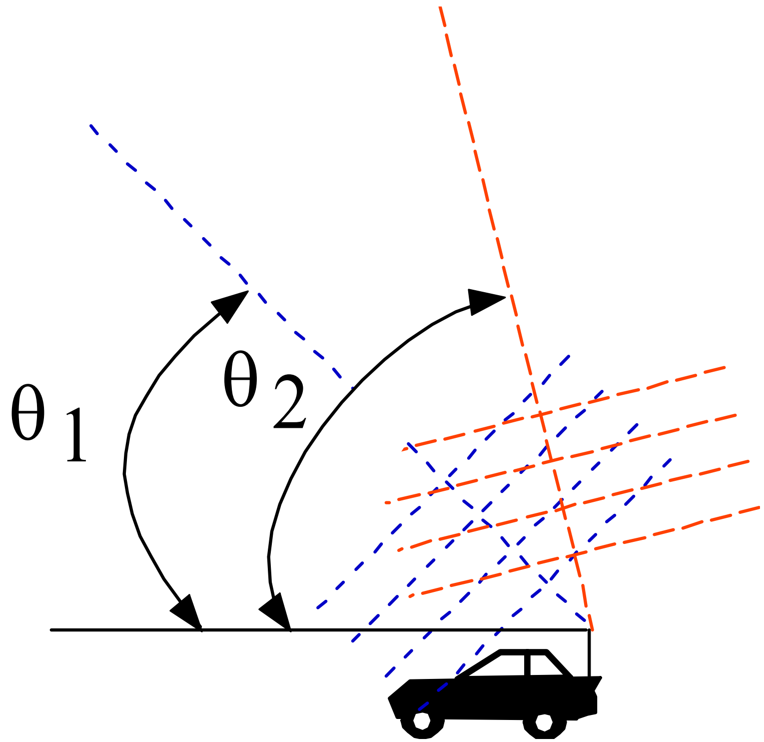
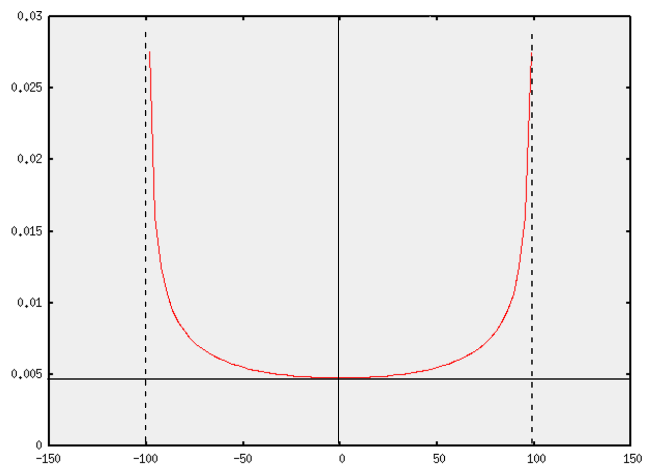
PSD 25 m/s
5 GHz
45.00
36.00
27.00
18.00
9.00
0.00
0.00
200.00
400.00
600.00
800.00
1000.00
Frequency, Hz



S(f)



f

$$S(f) = K \frac{1}{\pi f_m \sqrt{1 - \left(\frac{f - f_c}{f_m}\right)^2}}$$

Narrow Band Gaussian Random Process

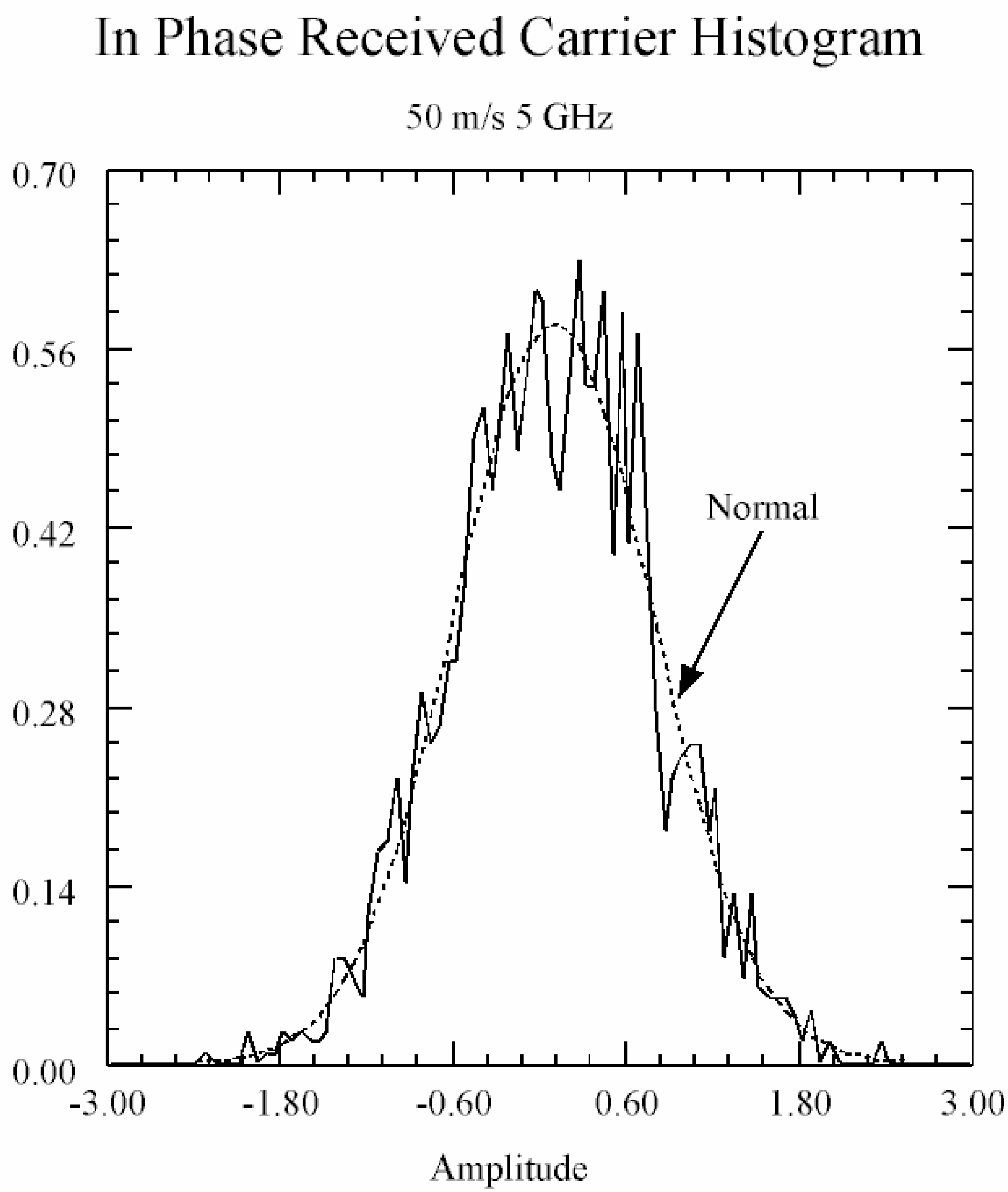
$$E_z = T_c(t)\cos 2\pi f_c t - T_s(t)\sin 2\pi f_c t$$

$$< T_c^2 >=< T_s^2 >= \frac{E_0^2}{2} =< |E_z|^2 >$$

$$< T_c T_s >= 0$$

$$p(x) = \frac{1}{\sqrt{2\pi b}} e^{-x^2/2b}$$

b is the variance


In Phase Received Carrier Histogram
50 m/s 5 GHz
0.70
0.56
0.42
0.28
0.14
0.00
-3.00
-1.80
-0.60
0.60
1.80
3.00
Normal
Amplitude

Envelope Rayleigh Distribution

$$E_z = T_c(t)\cos 2\pi f_c t - T_s(t)\sin 2\pi f_c t$$

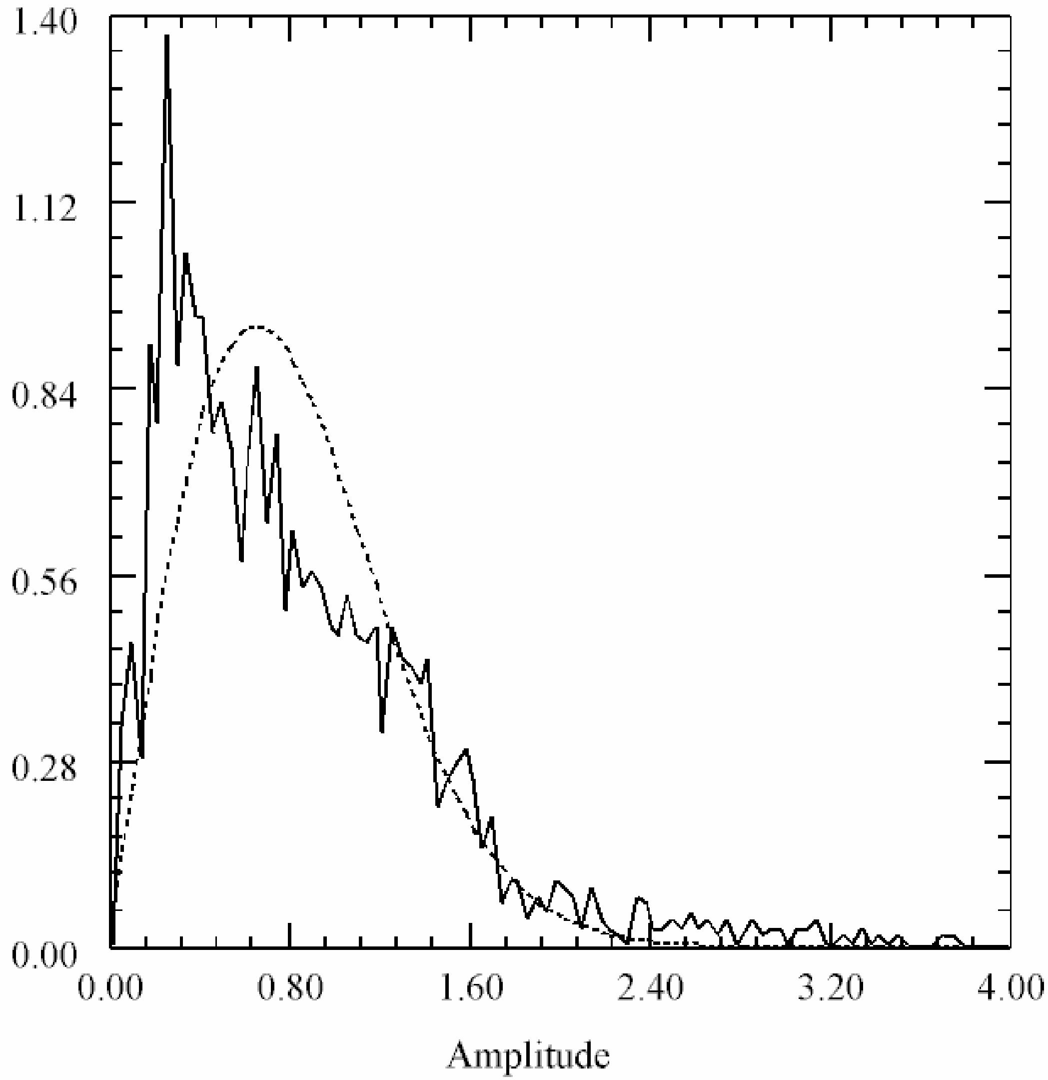
$$r = (T_c^2 + T_s^2)^{1/2}$$

$$p(r) = \frac{r}{b} e^{-r^2/2b} \qquad r \geq 0$$

$$p(r) = 0 \qquad r < 0$$

Envelope Received Carrier Histogram

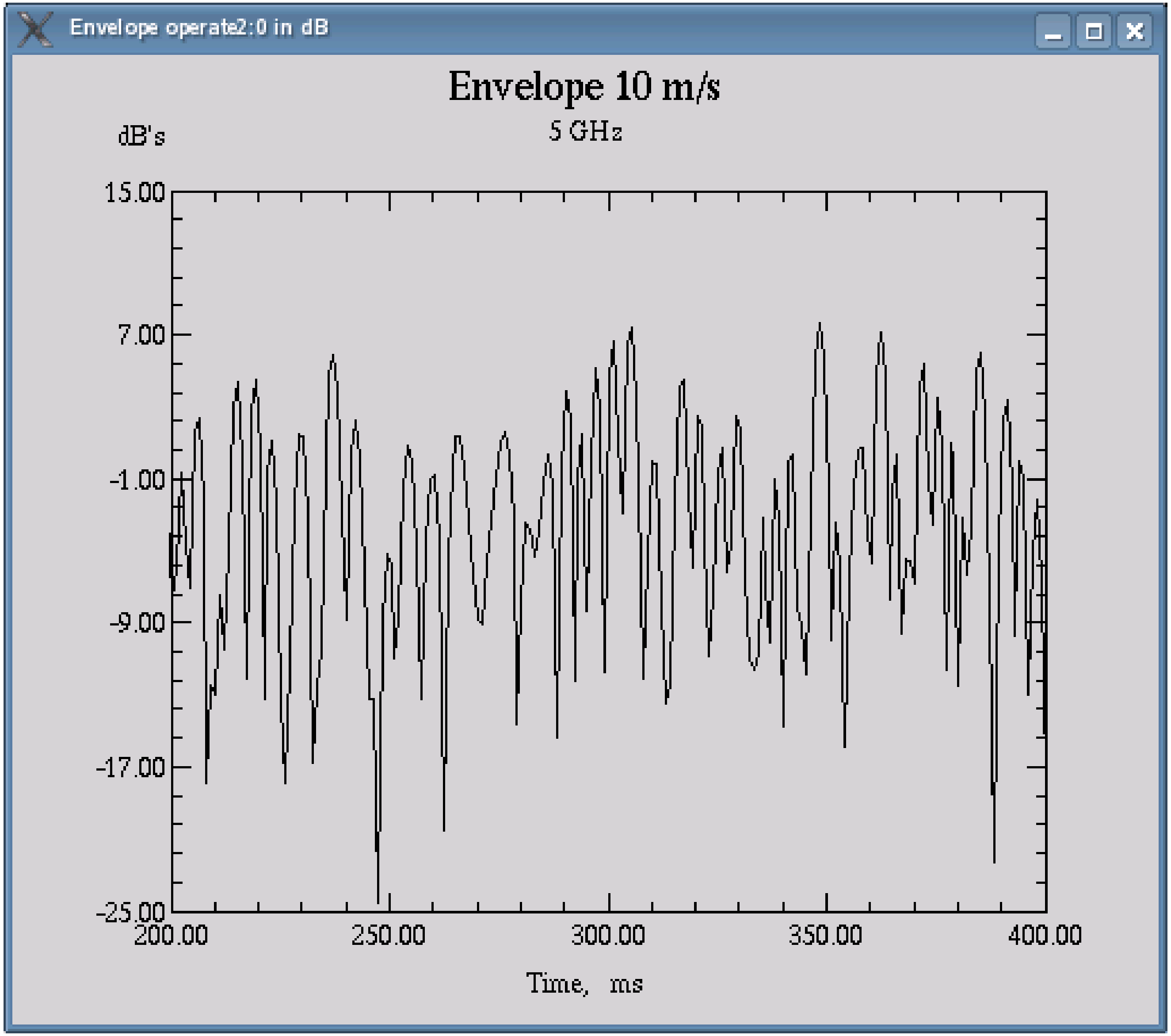
50 m/s 5 GHz



Fading Due to Motion

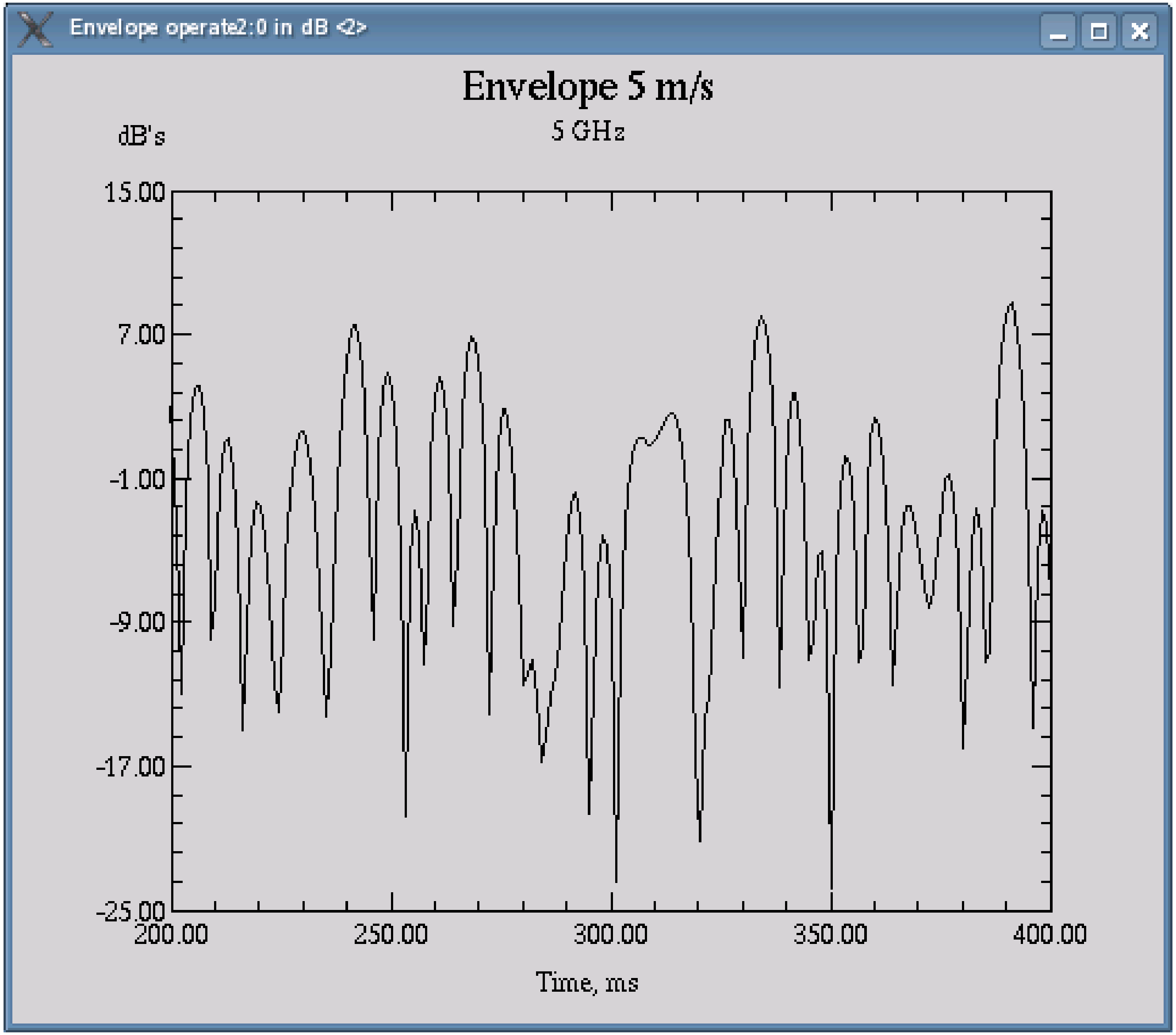
f_m=167 Hz

T_c=6 ms



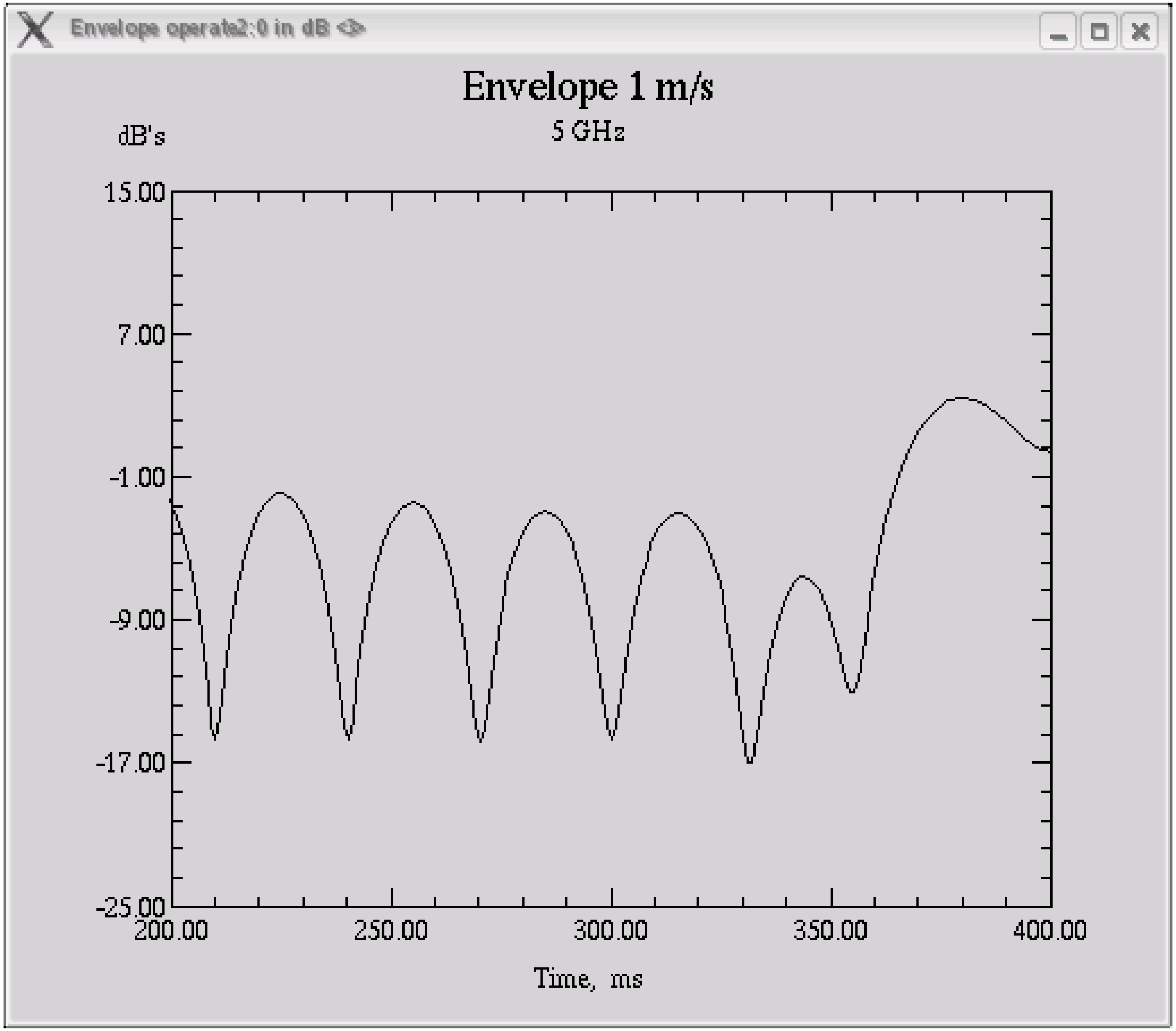
f_m=83.3 Hz

T_c=12 ms



f_m=16.7 Hz

T_c=60 ms

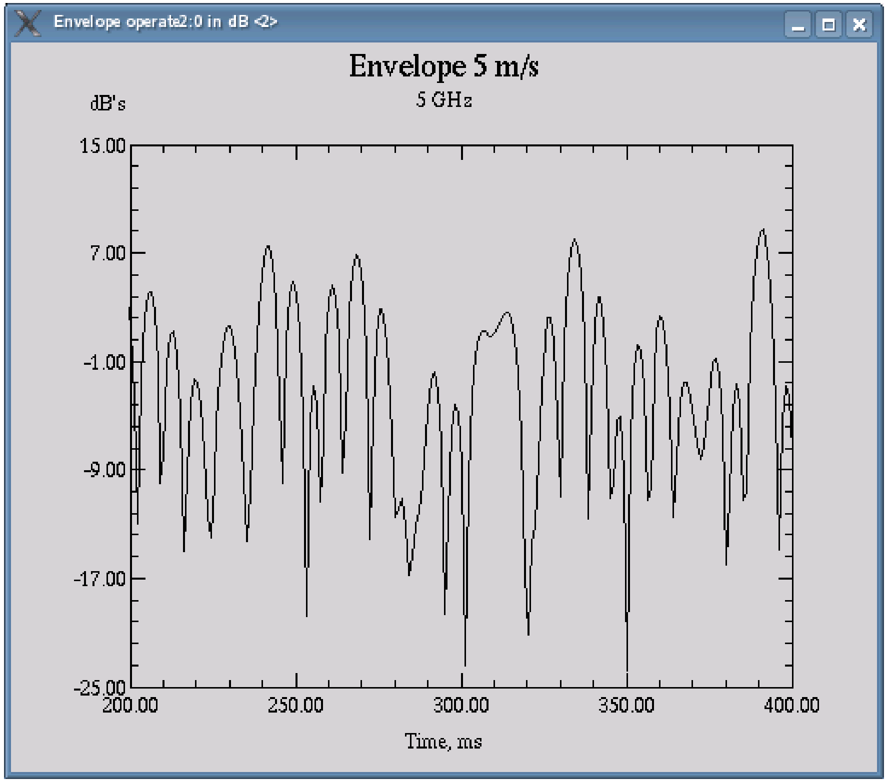


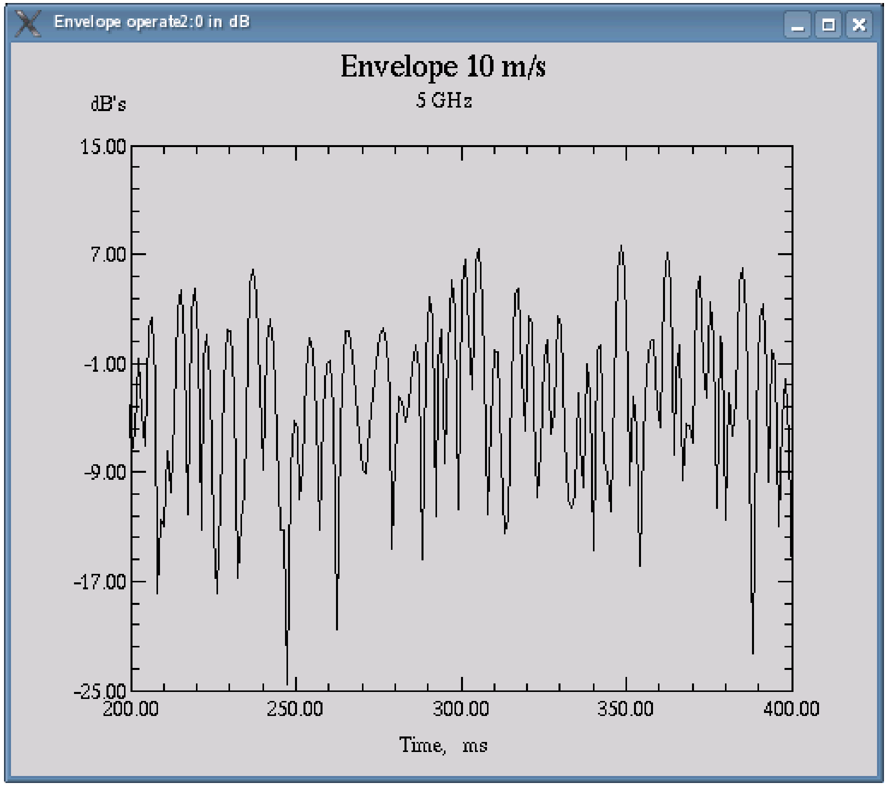
Level Crossing Rate

Expected rate at which the envelope crosses a specified level, R, in the positive direction.

$$\rho = \frac{R}{R_{rms}}$$

$$N_R = \sqrt{2\pi} f_m \rho e^{-\rho^2}$$

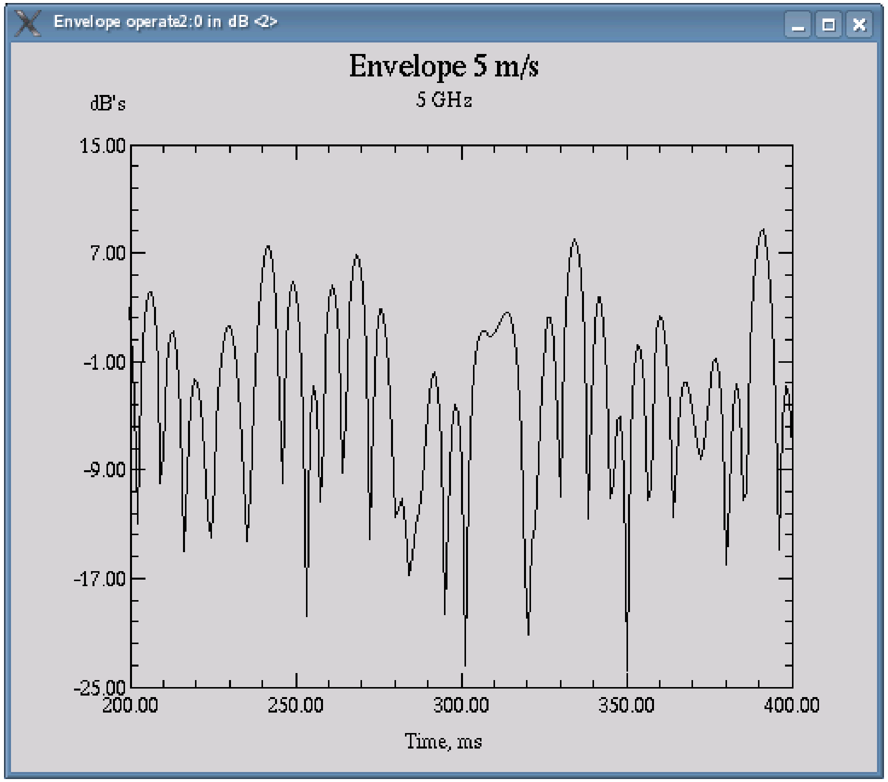


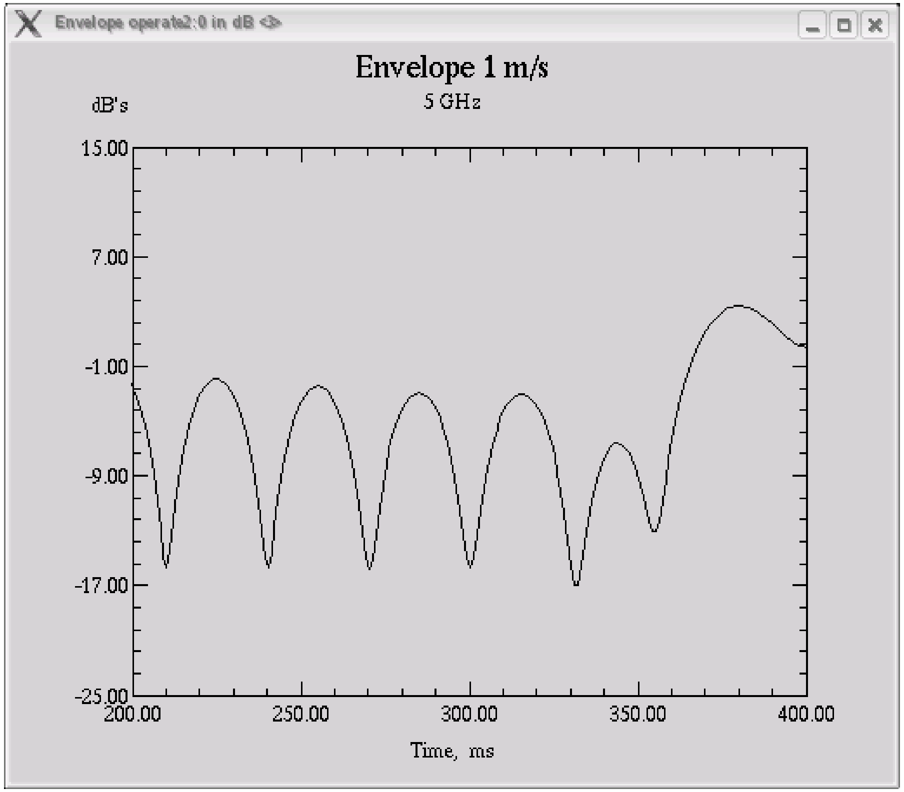


Duration of Fades

Average duration of fades below $r = R$.

$$\hat{\tau} = \frac{e^{\rho^2} - 1}{\rho f_m \sqrt{2\pi}} \qquad \rho = \frac{R}{R_{rms}}$$





Coherence Time

- Doppler Spread B_D

A measure of the spectral broadening caused by the time rate of change of the mobile radio channel

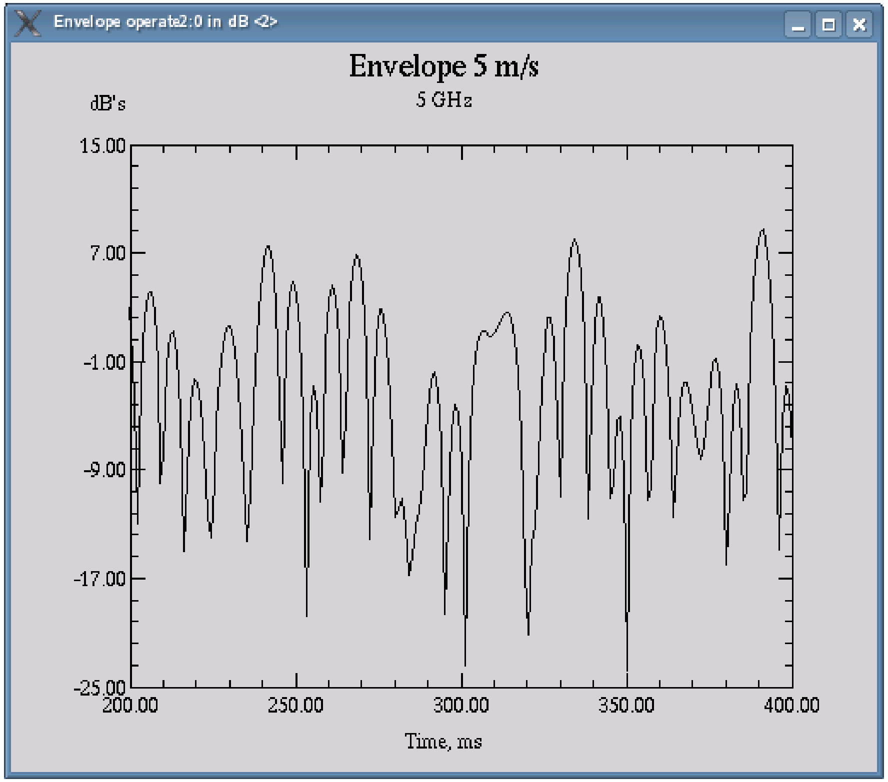
- Coherence Time

$$T_C \approx \frac{1}{f_m}$$

So packet length has to be much less than coherence time.

f_m=83.3 Hz

T_c=12 ms



f_m=16.7 Hz

T_c=60 ms