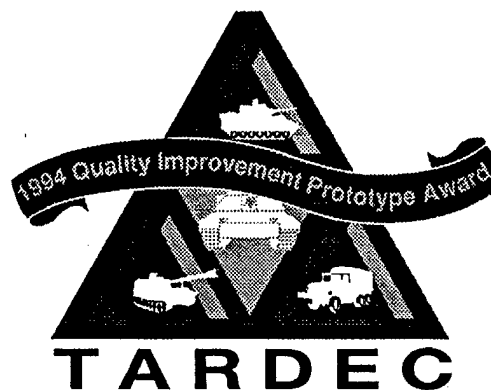


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---TECHNICAL REPORT---

THE NATION'S LABORATORY FOR ADVANCED AUTOMOTIVE TECHNOLOGY

No. **13761**



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Computer Generated Root-Mean-Square (RMS) Roughness Courses for Ride Quality Evaluation

By **Wesley W. Bylsma**

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U.S. Army Tank-Automotive Research,
Development, and Engineering Center
Detroit Arsenal
Warren, Michigan 48397-5000

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1. ABSTRACT

This report presents a suite of root-mean-square (RMS) computer generated ride quality courses in the range of 0.10 to 5.00 inches RMS for use in evaluating vehicle dynamics by computer simulation.

Power Spectral Density descriptions of each surface profile were used with digital simulation of stationary random processes to generate distance histories. Theoretical foundations and background on random processes and analysis of them are referenced.

For the specific example of surface profiles the mathematical preliminaries demonstrated the particular analytical techniques necessary to simulate random processes and apply it to surface profiles. In our examples the surface profile description was a one sided power spectral density function with defined constant slope frequency domain.

With the ability to simulate surface profiles and the -2 (log scale) slope description restriction the constant C was determined relating the surface roughness parameter, RMS, to the PSD surface profile description, allowing for the generation of a set of courses to simulate any desired level of surface roughness.

2. INTRODUCTION

One of the driving forces in evaluating vehicle dynamics is the surface profile. Simulations of vehicle dynamics are used to predict system performance based on human tolerance limits to vibration levels over a specified roughness course.

Descriptions of surface profiles have been presented in Van Deusen (1967), Dodds and Robson (1973), Healey et.al. (1977). A generalized case for relating random processes to surface profiles is addressed in Shinozuka (1971).

Computer generation of these RMS roughness courses is based on the simulation of stationary random processes, by which the designer can define the type of surface profile desired through frequency content and generate a time series.

2.1 Random Processes

Random processes are used to mathematically represent a surface profile since naturally occurring surfaces are not predefined and depending on the current geographical area do have variability in them. Naturally occurring phenomenon

and environmental conditions, such as rain, wind, snow, and temperature fluctuations cause changes to occur. For in-depth coverage of random processes Papoulis (1984) is highly recommended.

2.2 Power Spectral Density

To generate roughness courses the fundamental relationship between the Power Spectral Density (PSD) function, $S_g(w)$, and the distance domain, $g(x)$, needs to be found where the PSD is the Fourier Transform of the auto-correlation function

$$S_g(w) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} R_g(\tau) e^{-jw\tau} d\tau \quad (1)$$

and the auto-correlation function can be gotten from the PSD through the inverse Fourier Transform

$$R_g(\tau) = \int_{-\infty}^{+\infty} S_g(w) e^{jw\tau} dw \quad (2)$$

where

$$R_g(\tau) = E[g(x+\tau)g^*(x)] \quad (3)$$

with $E[\]$ being defined as the standard expectation operator. For real-valued random processes the auto-correlation function is even which reduces the PSD to

$$S_g(w) = \int_{-\infty}^{+\infty} R_g(\tau) \cos(w\tau) d\tau \quad (4)$$

giving a real-valued, even PSD of w .

2.3 Random Process Simulation

Simulation of the random process requires the use of the relationship between the surface profile function $g(x)$ and the PSD function $S_g(w)$. The forward operation

$$g(x) \rightarrow S_g(w) \quad (5)$$

known as the PSD is defined in (1). Proakis and Manolakis (1988) discuss many well known methods for calculating PSD's. Less obvious is the reverse operation

$$S_g(w) \rightarrow g(x) \quad (6)$$

The difficulty lies in that $g(x)$ is in terms of the auto-correlation function. A direct extraction of $g(x)$ from $R_g(\tau)$ is problematic.

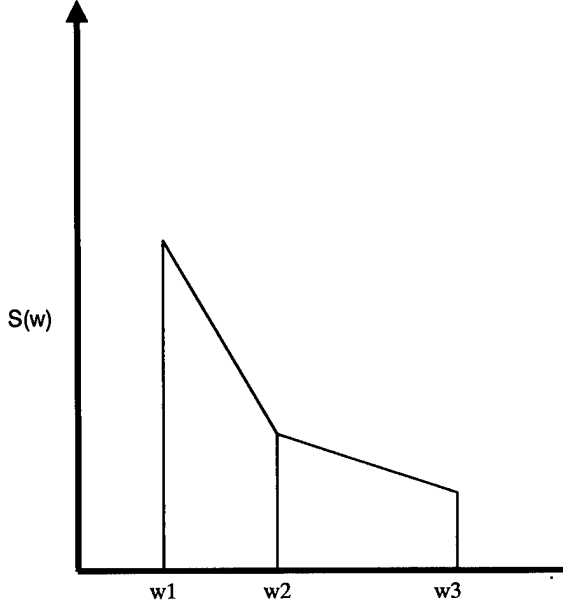


Figure 1 - Example Power Spectral Density function

From (2) and (3) the expected value relates the distance function to the PSD identifying a relationship that will satisfy (6). Through the use of trigonometric identities and conveniently chosen probability distributions Shinozuka and Jan (1972) determined the relationship to be

$$g(x) = \sqrt{2} \sum_{k=1}^N \sqrt{S_g(w_k) \Delta w_k} \cos(w'_k x + \phi_k) \quad (7)$$

where ϕ is a random phase angle uniformly distributed between 0 and 2π ,

$$\Delta w_k = \frac{w_{upper} - w_{lower}}{N} \text{ with } w_{upper} = w_3 \text{ and}$$

$$w_{lower} = w_1 \text{ as depicted in Figure 1,}$$

$$w_k = w_{lower} + (k - 0.5)\Delta w_k, \text{ and}$$

$$w'_k = w_k + \delta w \text{ where } \delta w \text{ is uniformly distributed}$$

$$\text{between } \frac{-\Delta w'_k}{2} \text{ and } \frac{+\Delta w'_k}{2} \text{ where}$$

$$\Delta w'_k \ll \Delta w_k \text{ to avoid periodicity.}$$

Equation (7) assumes a zero mean, both in ensemble average and temporal mean. Shinozuka and Jan (1972) detail the theoretical basis for these requirements and show the applicability of this

method to the multi-dimensional case.

2.4 Generation of Surface Profiles

It is generally accepted that the PSD of a surface profile can be represented as

$$S_g(w) = \begin{cases} c_1 w^{-n_1}, & w_1 \leq w < w_2 \\ c_2 w^{-n_2}, & w_2 \leq w < w_3 \end{cases} \quad (8)$$

as shown in Figure 1.

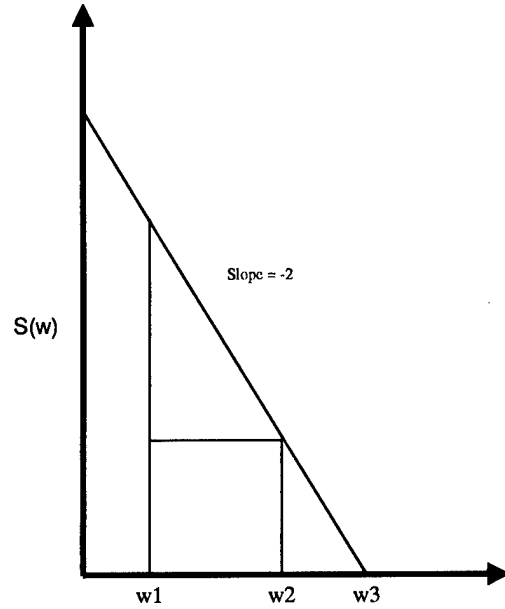


Figure 2 - Example Power Spectral Density function with constant -2 slope

As noted by Sevin and Pilkey (1971) most surfaces can be approximated by

$$S_g(w) = cw^{-2}, \quad w_1 \leq w < w_3 \quad (9)$$

alone. For this special case note the logarithmic plot is

$$\log(S_g(w)) = -2\log(w) + \log(c) \quad (10)$$

which produces a straight line with slope of -2 as shown in Figure 2.

Further, Parseval's Theorem states that the variance of $g(x)$ is the area under $S_g(w)$. An often used measure of surface roughness is the root-mean-square (RMS) value

$$RMS = \sqrt{\frac{1}{L} \int_0^L g(x)^2 dx} = \sigma \quad (11)$$

which is the standard deviation, σ , or the square-root of the variance for zero-mean $g(x)$. Given the -2 slope assumption in (10) and using Parseval's Theorem c is directly related to RMS by

$$c = (RMS)^2 \frac{w_1 w_2}{(w_2 - w_1)} \quad (12)$$

For various levels of RMS roughness the corresponding c can be found and used to define the PSD from Figure 2 which, when simulated, will produce a course with the desired roughness.

The more general case in (8) adds flexibility to the surface profile description of the PSD which it estimates, although it has been found that (9) can give a good approximation to the PSD within a band of ± 3 dB.

Ashmore and Piersol (1997) have determined surface profiles based on the definition in (9) for military and commercial roads.

3. RESULTS

The following pages show figures of the generated surface profiles from 0.10 to 5.00 inch RMS in 0.1 increments. Each is 1000 feet with 3 inch samples (4000 points). Each contains the PSD plot with original surface profile description, $S_g(w)$, between ± 3 dB bands and circle points of the PSD generated from $g(x)$ in the first pane. The second pane is a sectional plot of $g(x)$, with the third pane containing a histogram of the full signal. Dimensional units are

not included with the plots but are in $\frac{ft^2}{1/ft}$ for

$S_g(w)$ and ft for $g(x)$. The shape of the histogram should be noted as that of a Gaussian distribution, with parameters of $\mu = 0$, the mean, and σ , the standard deviation. This should not be surprising since the Central Limit Theorem of random variables applies from the summation in (7). Increased RMS levels are also shown by the spread out histogram which corresponds to greater σ since the area of $S_g(w)$ is related to RMS through Parseval's Theorem.

For each RMS level (0.10 - 5.00 inches in 0.1 increments) ten surface profiles $g(x)$ were generated. Figures 3-52 show only one of these for each RMS level. Figures 53-102 are plots of each profile in its entirety with units of inches versus feet. Figures 103-105 show the comparative RMS level between 1.00, 3.00, and 5.00 inch RMS courses all plotted on the same scale (-20 to 20 inches). For reasons of brevity, an example listing of the surface profile (5.00) file is included for reference purposes. Each file is in American Standard Code for Information Interchange (ASCII) with the following format:

```

---BOF---
label
length (points), spacing (inches)
elevation point #0 (inches)
elevation point #1 (inches)
.
.
.
---EOF---
```

Below is a specific example.

```

---BOF---
RMS ROUGHNESS COURSE 1
4000, 3.0
0.0123
0.1236
-0.0900
.
.
.
---EOF---
```

For each elevation point the distance is point#*spacing (starting at zero).

3.1 RMS Course PSD's

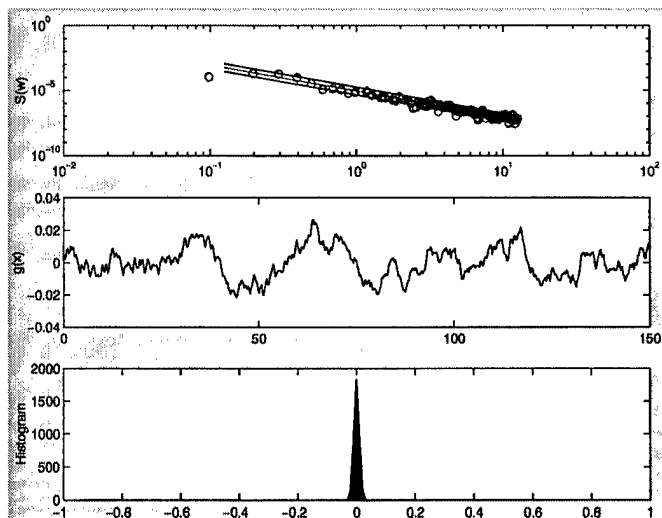


Figure 3 - 0.10" RMS

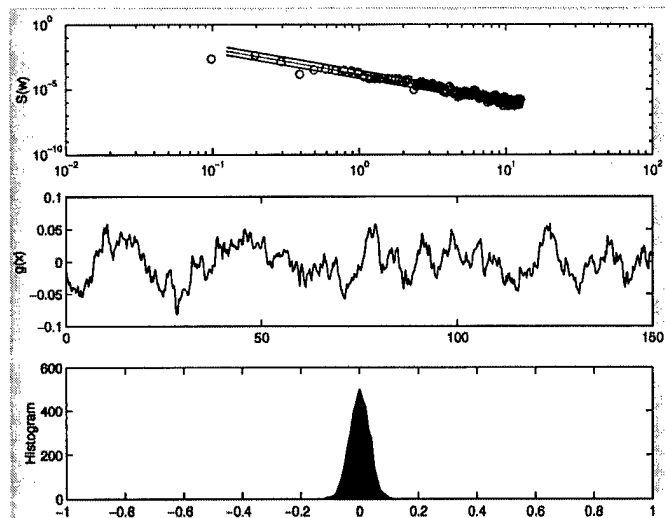


Figure 6 - 0.40" RMS

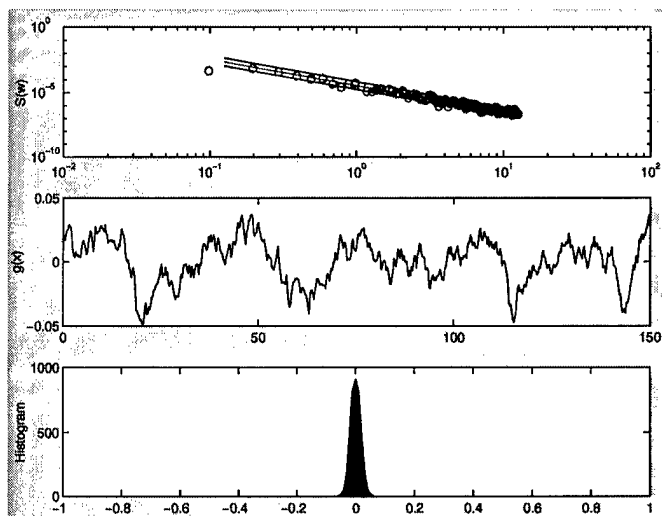


Figure 4 - 0.20" RMS

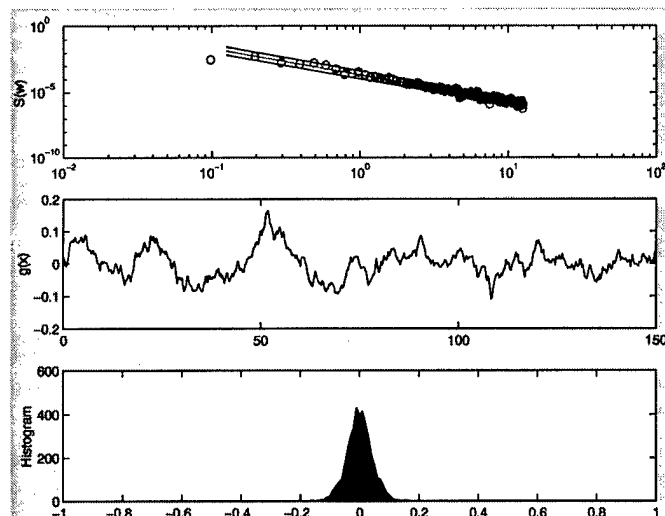


Figure 7 - 0.50" RMS

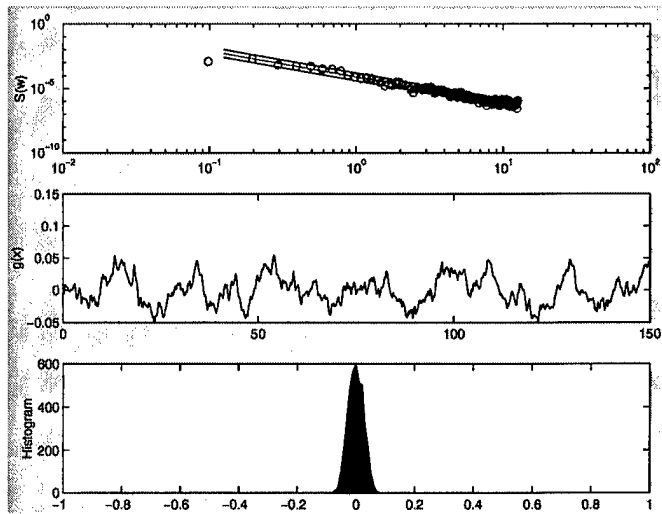


Figure 5 - 0.30" RMS

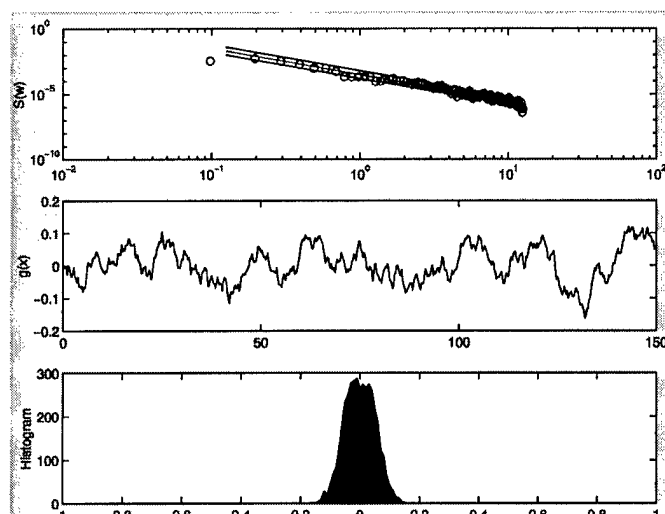


Figure 8 - 0.60" RMS

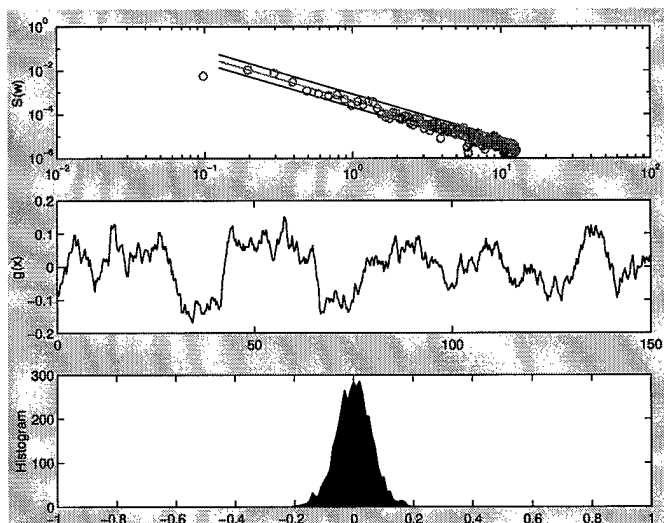


Figure 9 - 0.70" RMS

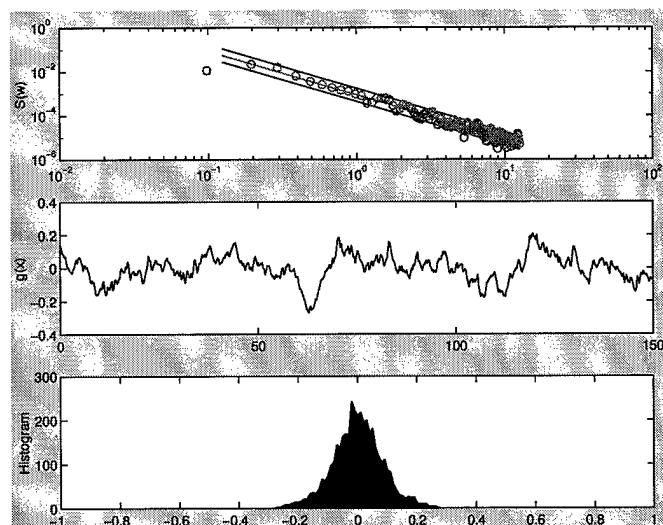


Figure 12 - 1.00" RMS

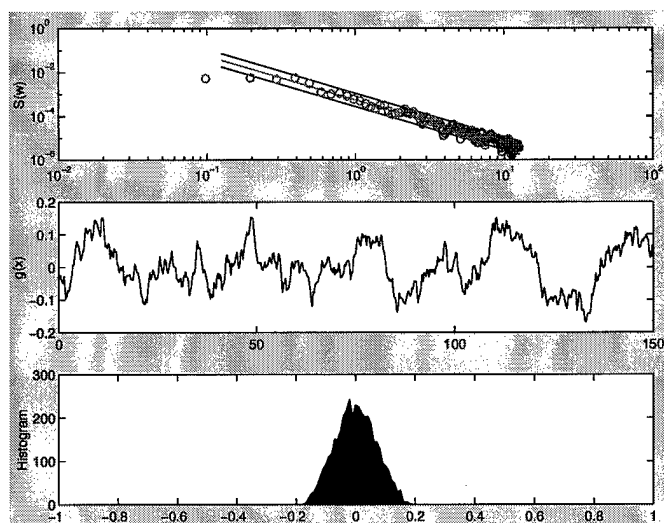


Figure 10 - 0.80" RMS

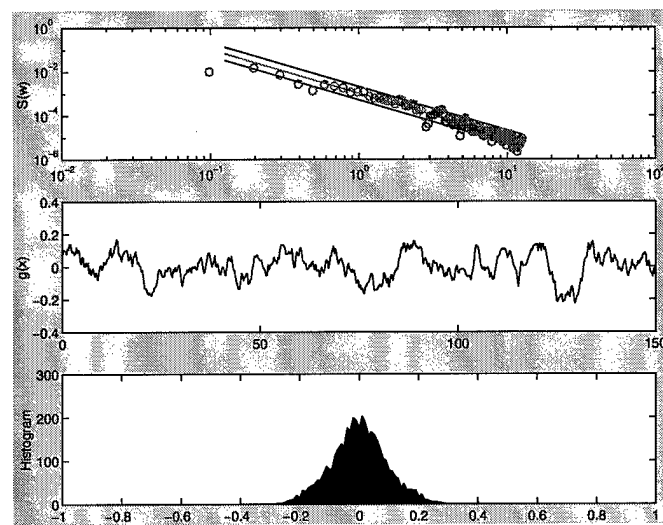


Figure 13 - 1.10" RMS

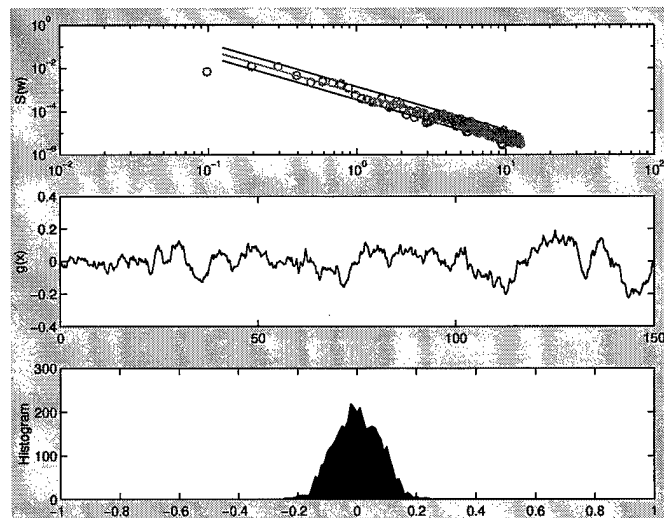


Figure 11 - 0.90" RMS

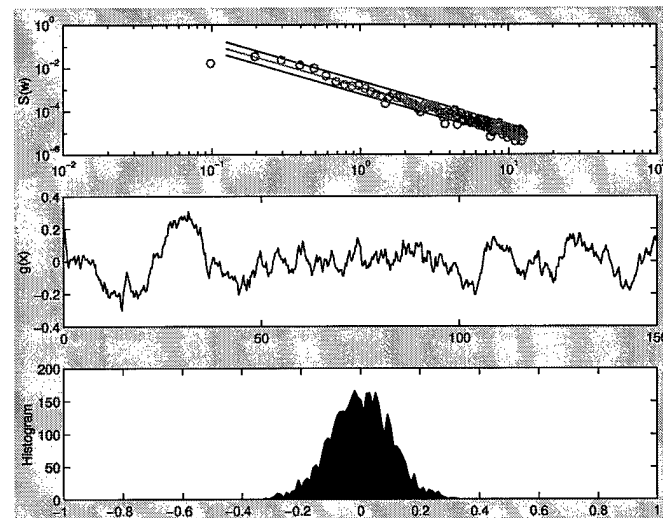


Figure 14 - 1.20" RMS

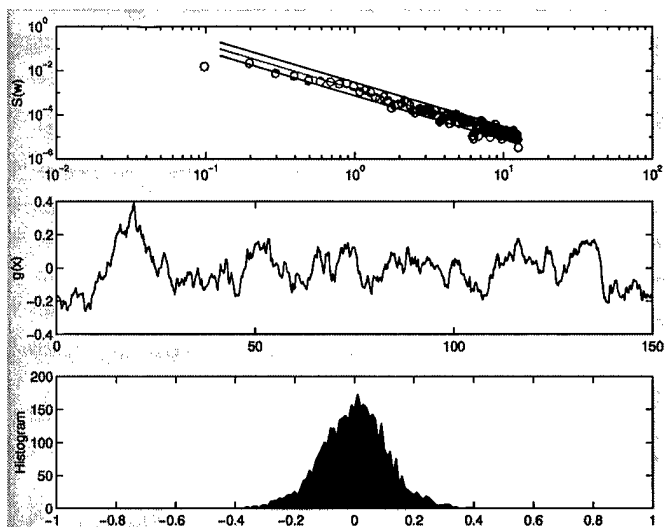


Figure 15 - 1.30" RMS

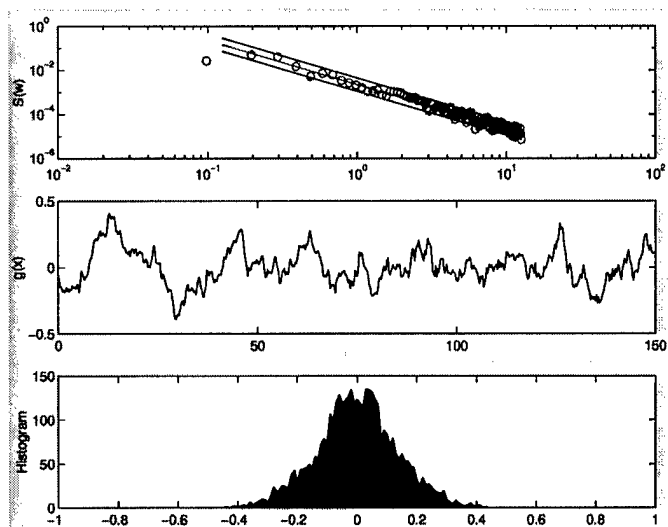


Figure 18 - 1.60" RMS

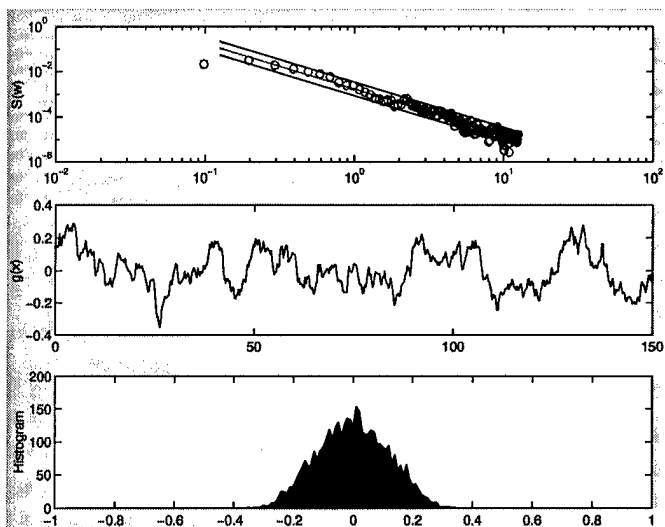


Figure 16 - 1.40" RMS

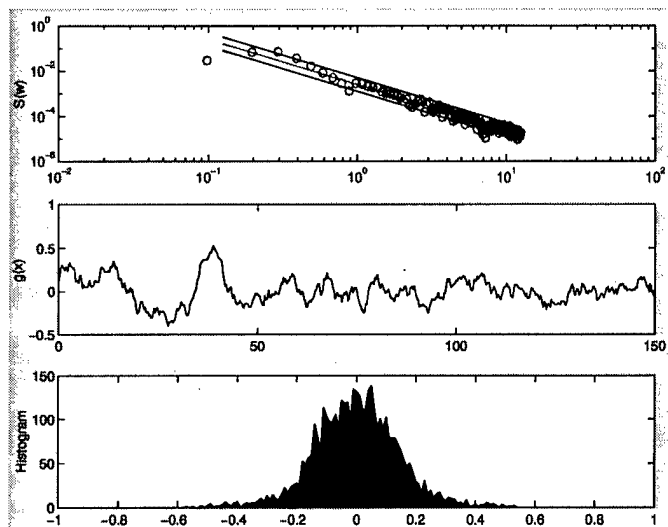


Figure 19 - 1.70" RMS

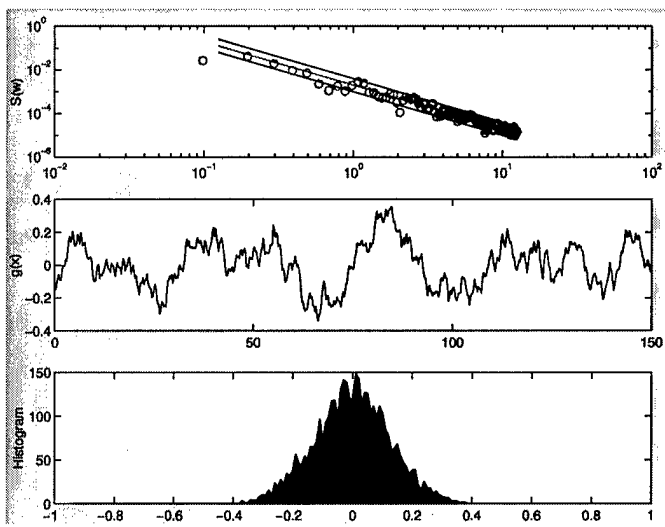


Figure 17 - 1.50" RMS

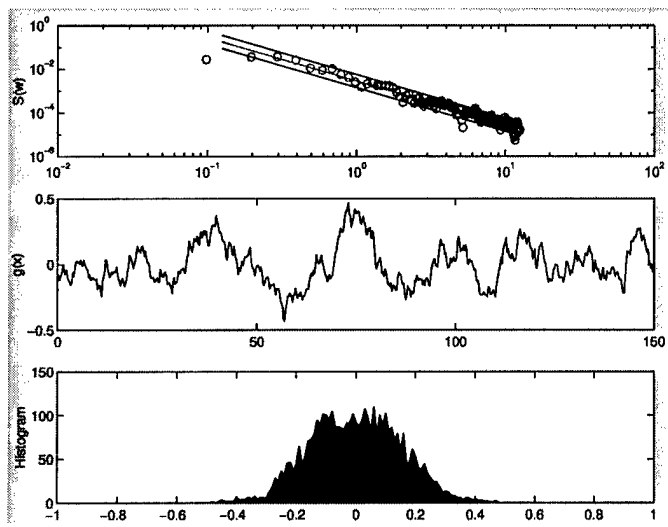


Figure 20 - 1.80" RMS

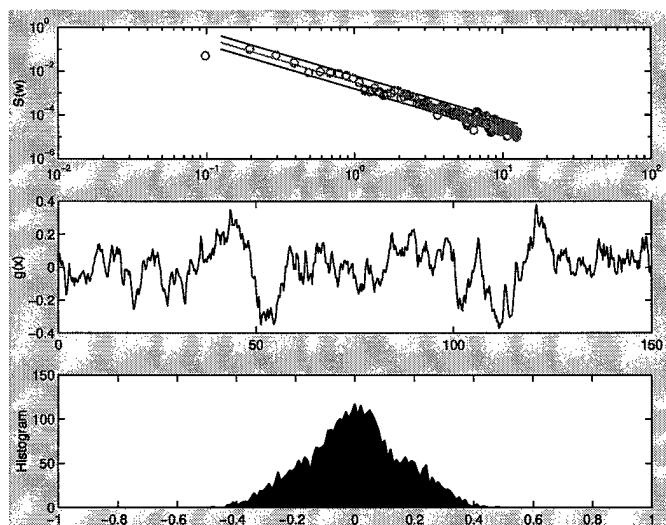


Figure 21 - 1.90" RMS

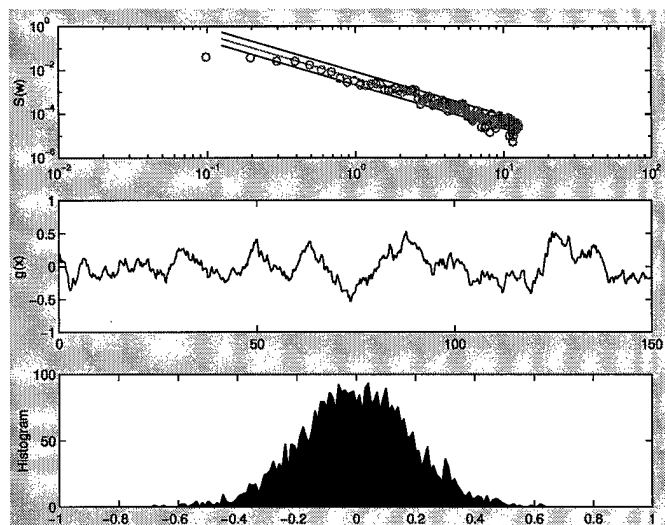


Figure 24 - 2.20" RMS

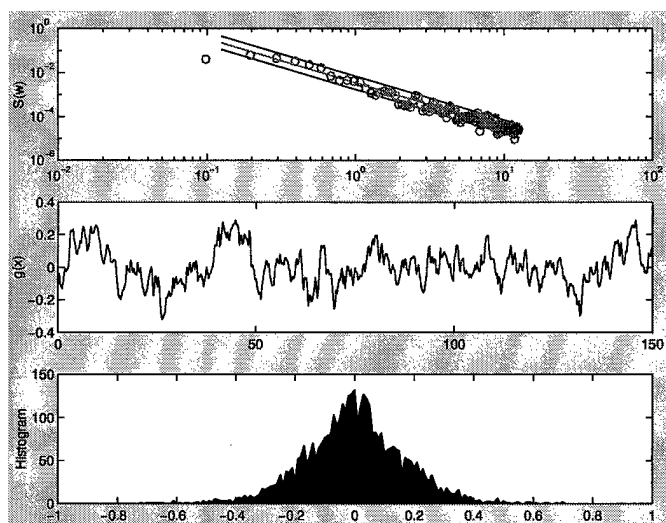


Figure 22 - 2.00" RMS

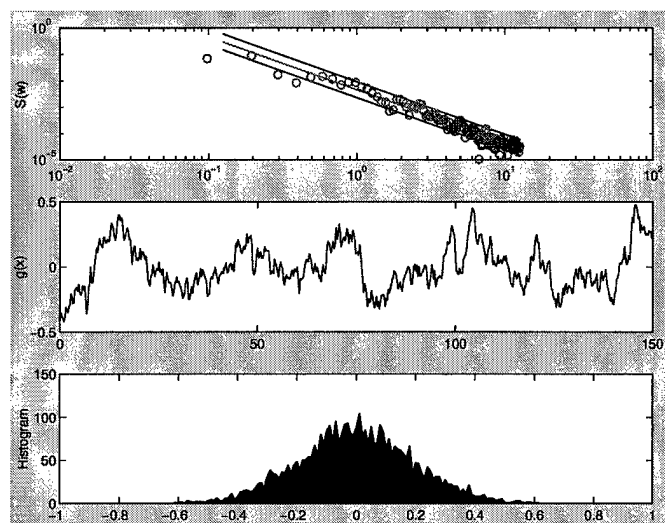


Figure 25 - 2.30" RMS

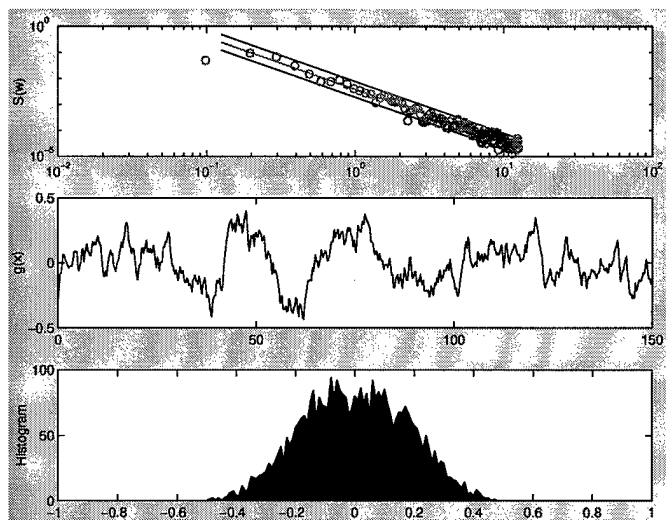


Figure 23 - 2.10" RMS

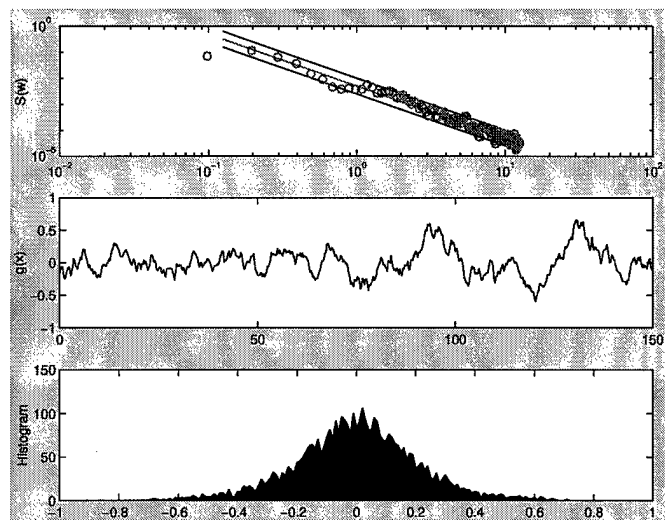


Figure 26 - 2.40" RMS

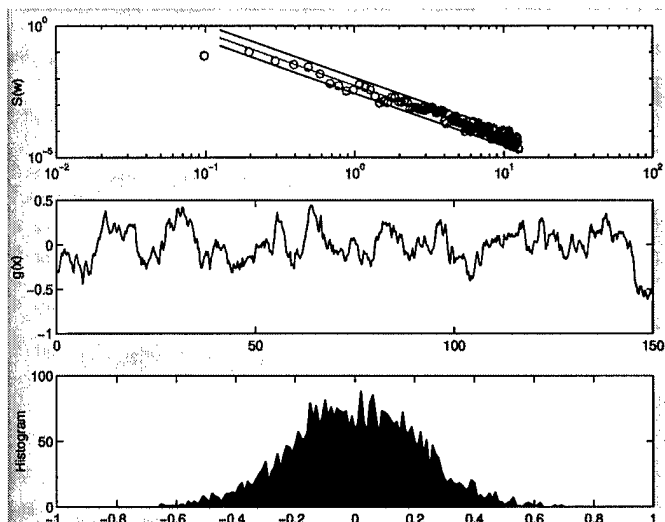


Figure 27 - 2.50" RMS

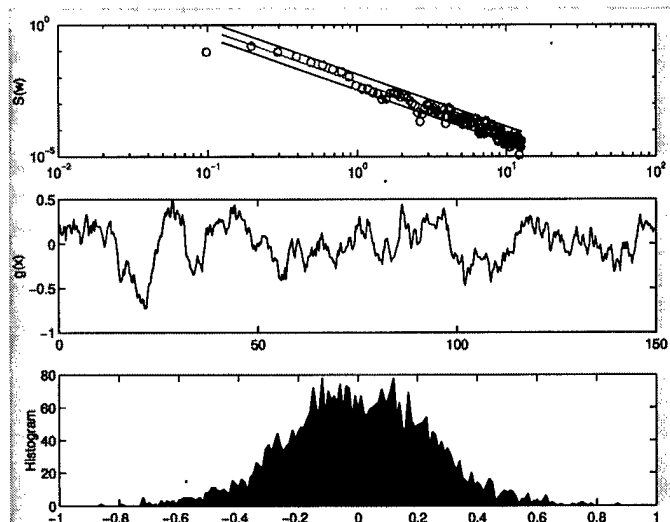


Figure 30 - 2.80" RMS

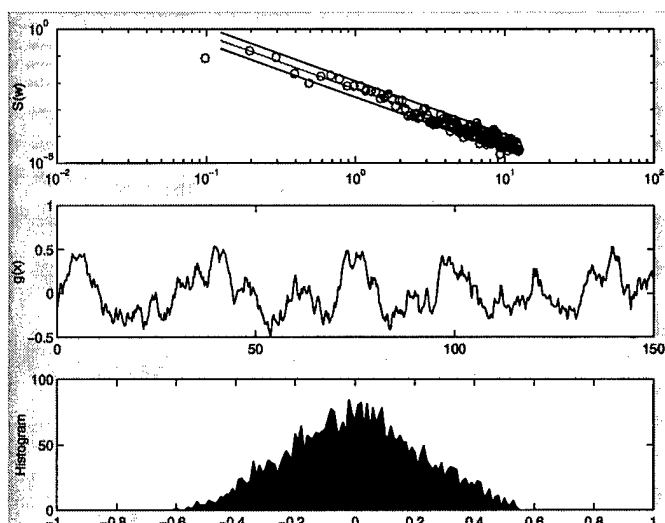


Figure 28 - 2.60" RMS

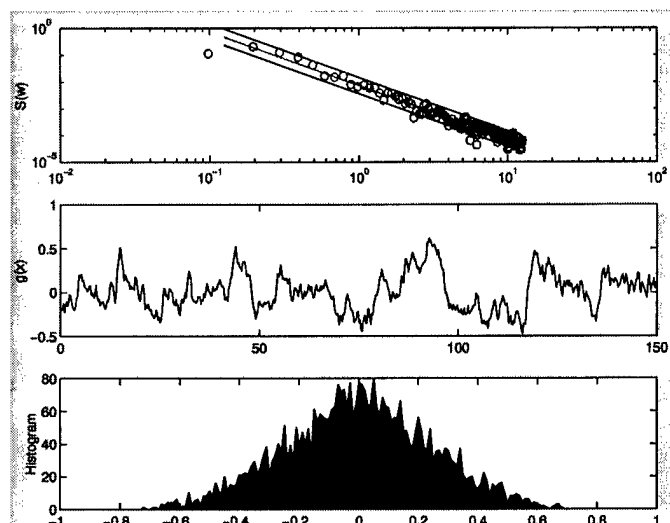


Figure 31 - 2.90" RMS

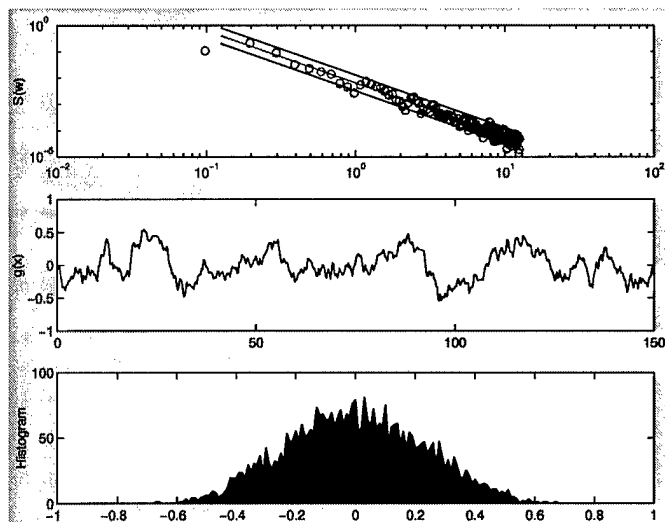


Figure 29 - 2.70" RMS

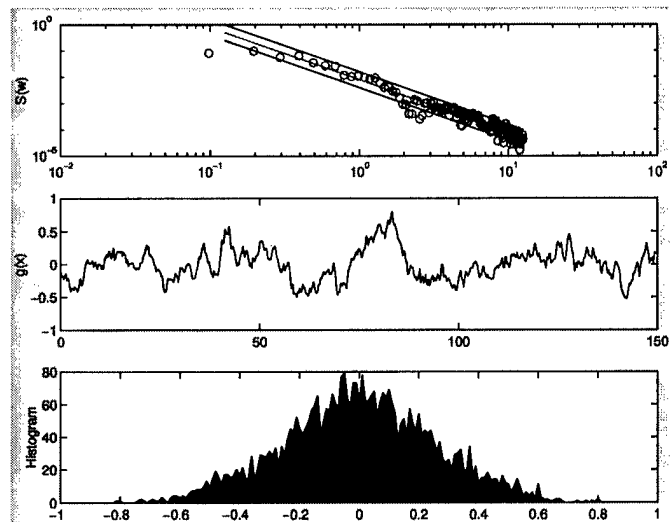


Figure 32 - 3.00" RMS

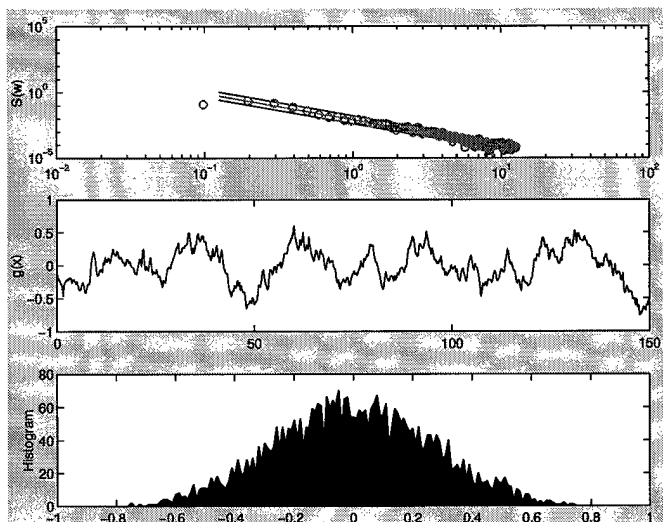


Figure 33 - 3.10" RMS

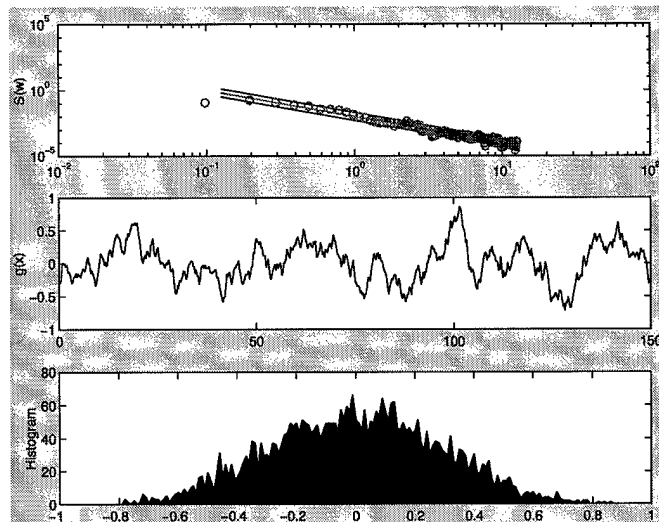


Figure 36 - 3.40" RMS

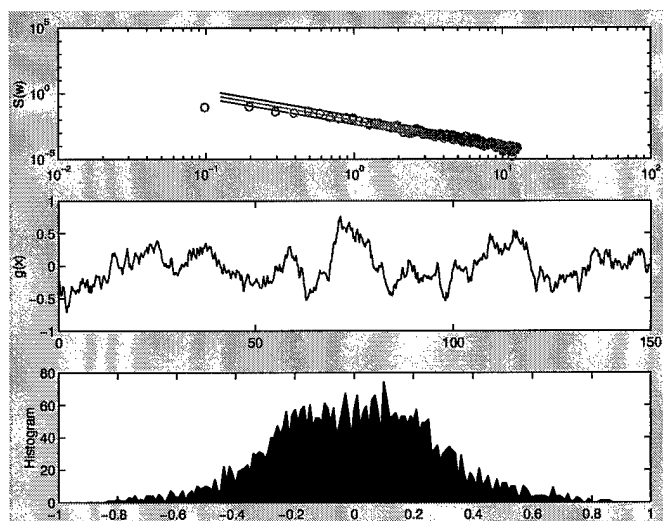


Figure 34 - 3.20" RMS

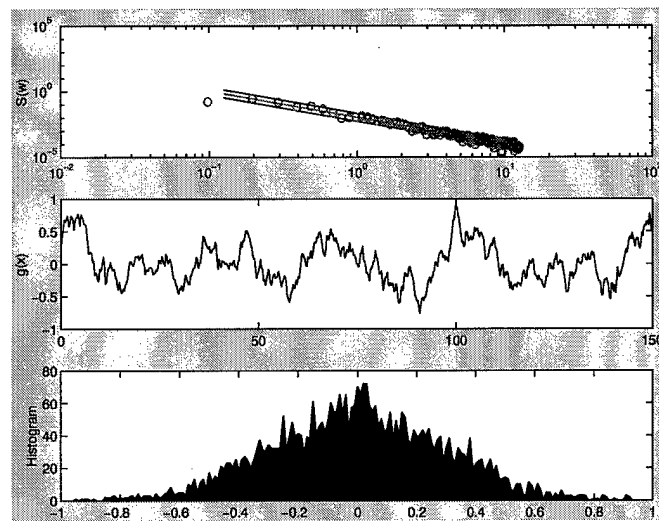


Figure 37 - 3.50" RMS

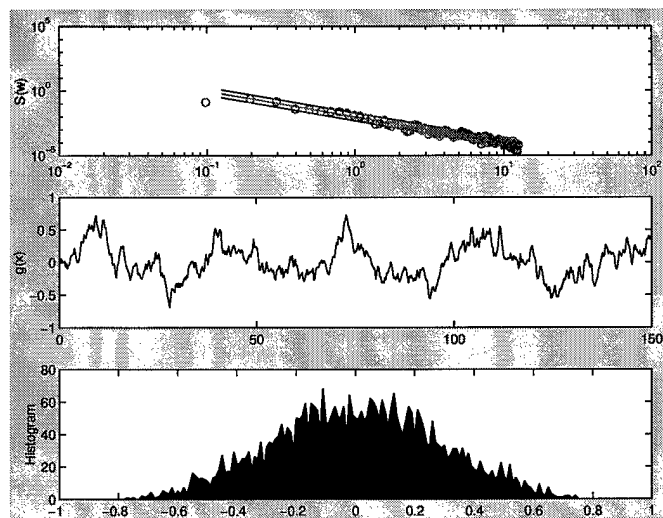


Figure 35 - 3.30" RMS

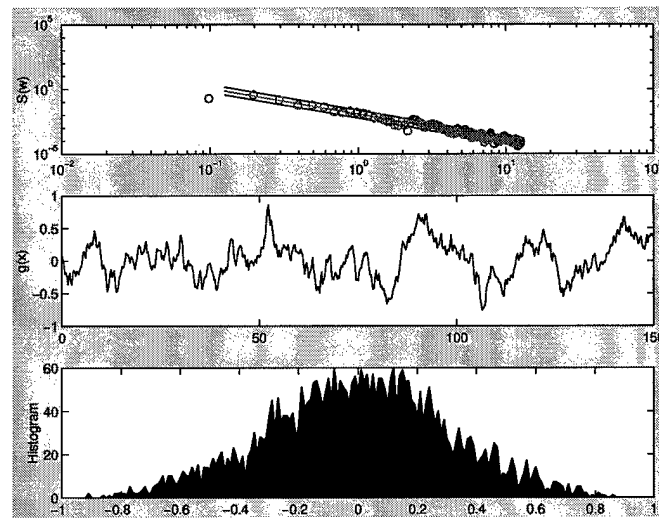


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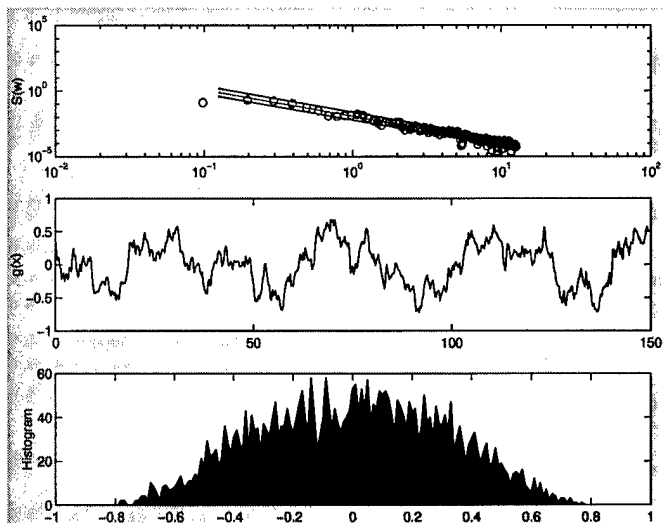


Figure 39 - 3.70" RMS

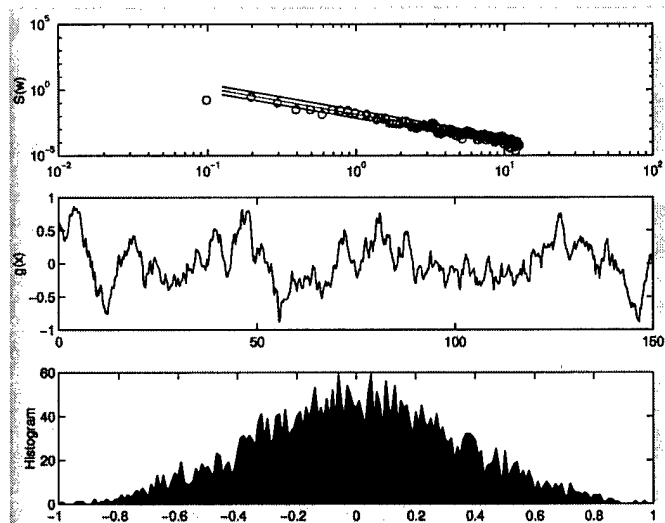


Figure 42 - 4.00" RMS

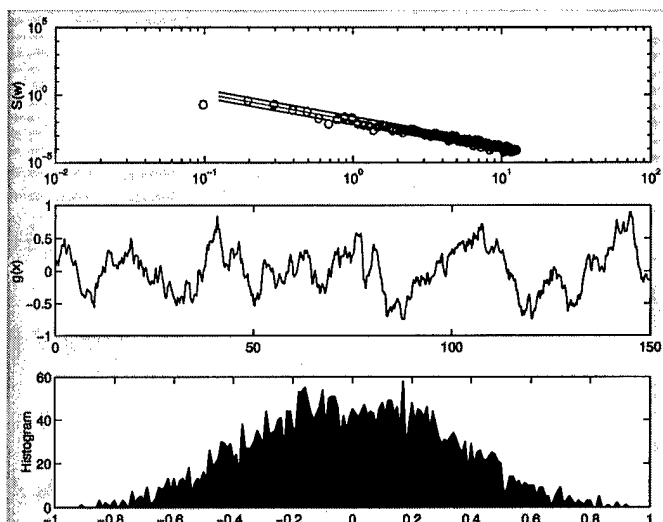


Figure 40 - 3.80" RMS

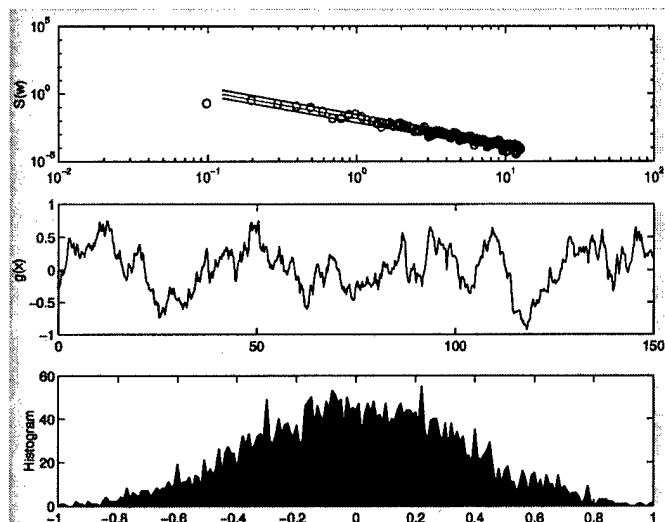


Figure 43 - 4.10" RMS

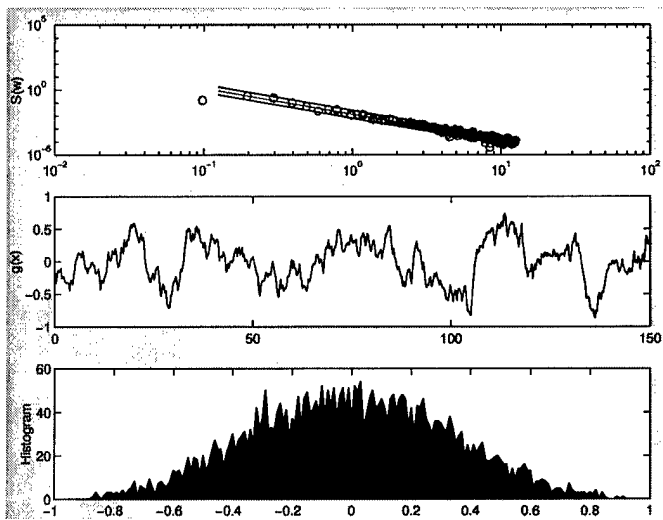


Figure 41 - 3.90" RMS

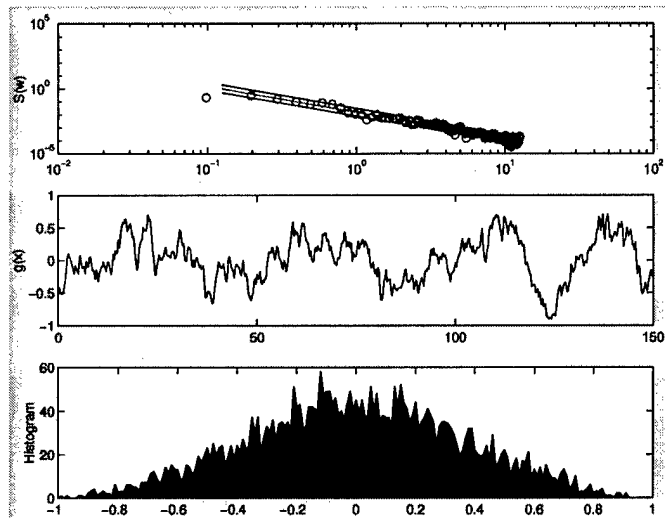


Figure 44 - 4.20" RMS

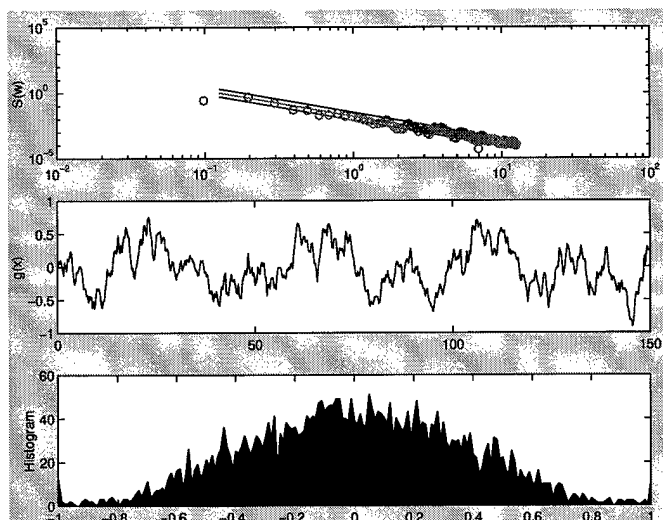


Figure 45 - 4.30" RMS

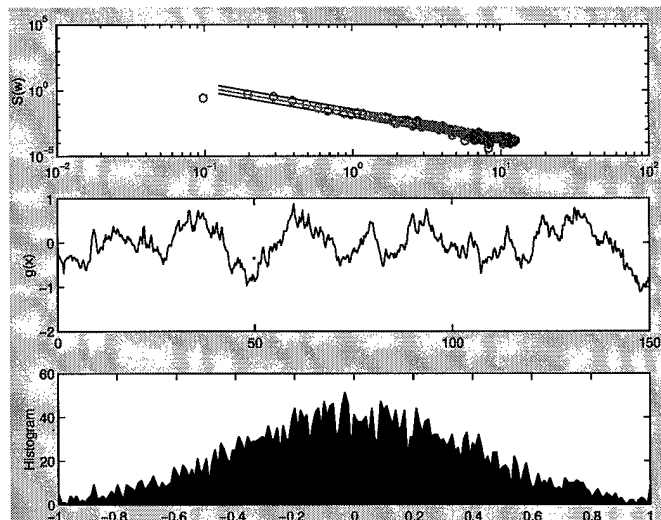


Figure 48 - 4.60" RMS

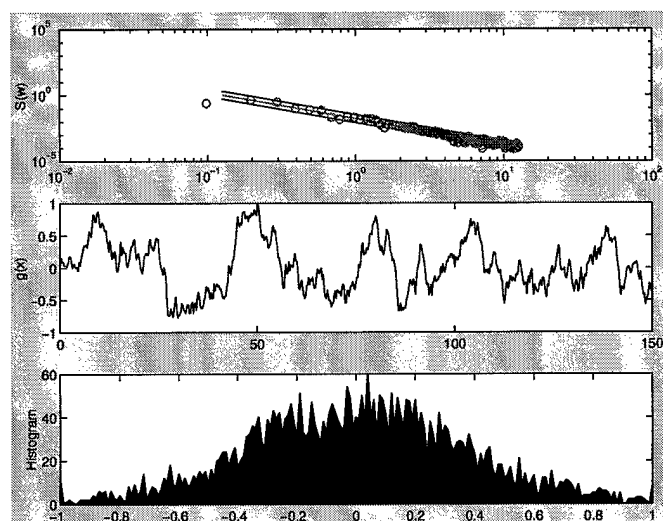


Figure 46 - 4.40" RMS

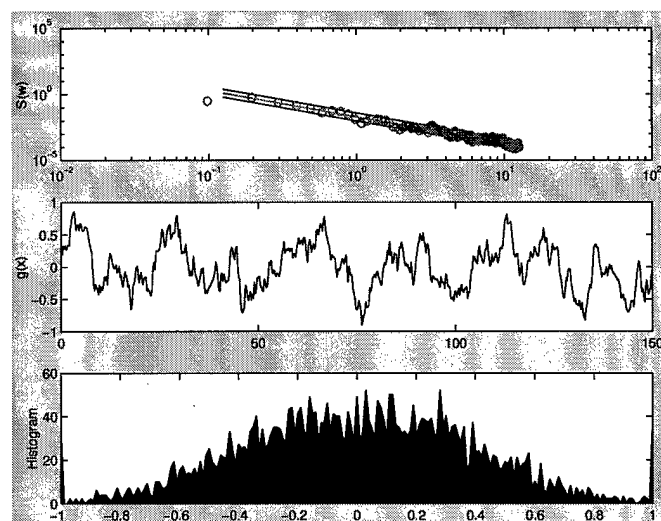


Figure 49 - 4.70" RMS

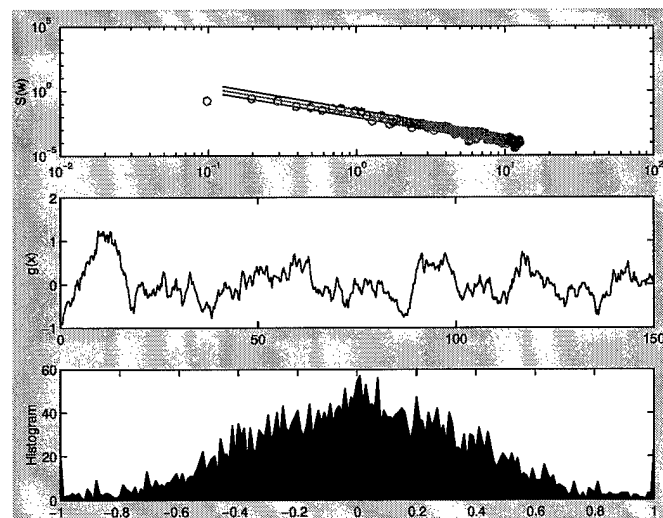


Figure 47 - 4.50" RMS

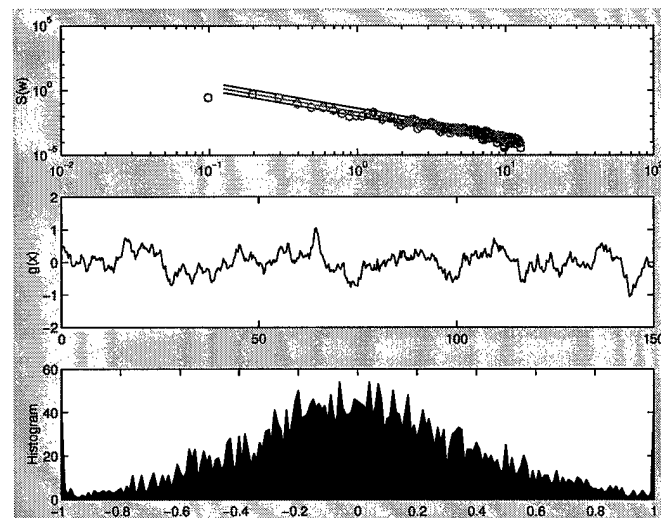


Figure 50 - 4.80" RMS

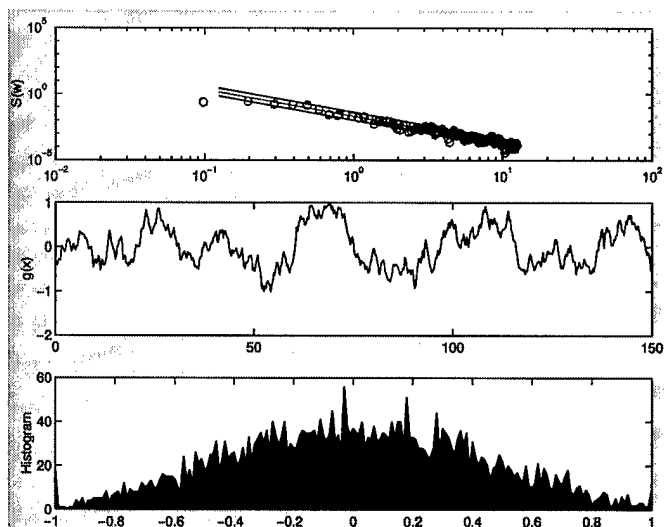


Figure 51 - 4.90" RMS

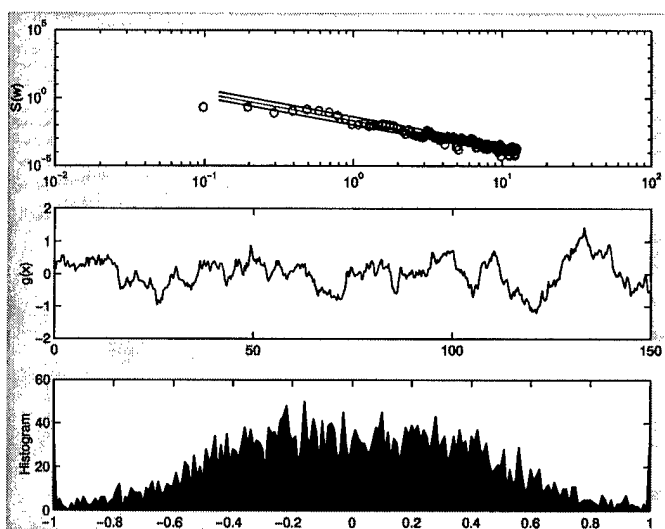


Figure 52 - 5.00" RMS

3.2 Full RMS Course Plots

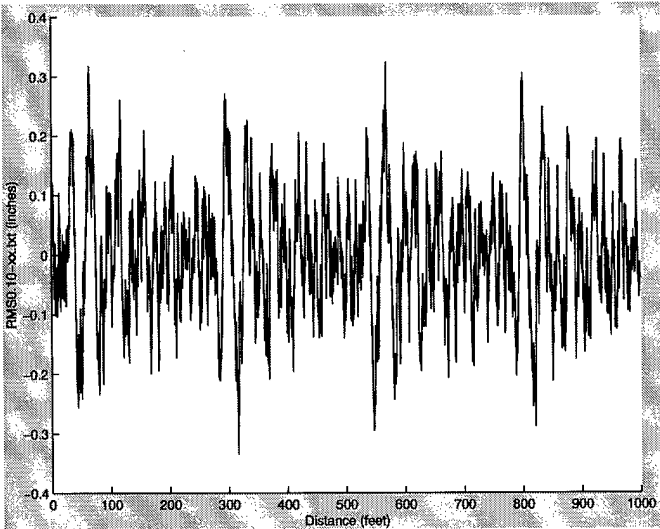


Figure 53 - 0.10" RMS

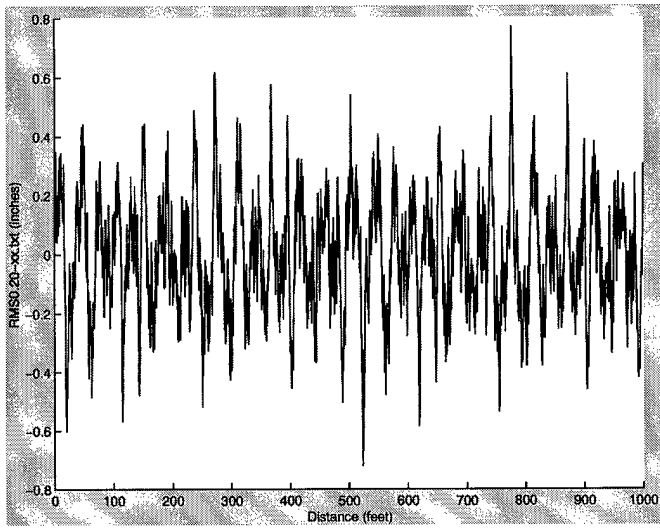


Figure 54 - 0.20" RMS

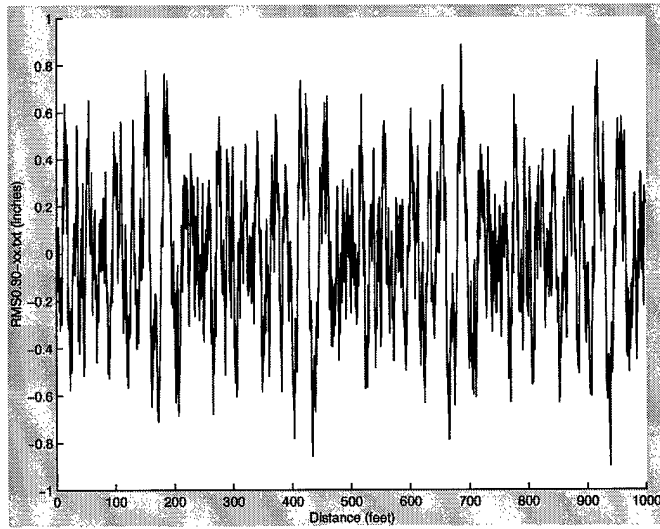


Figure 55 - 0.30" RMS

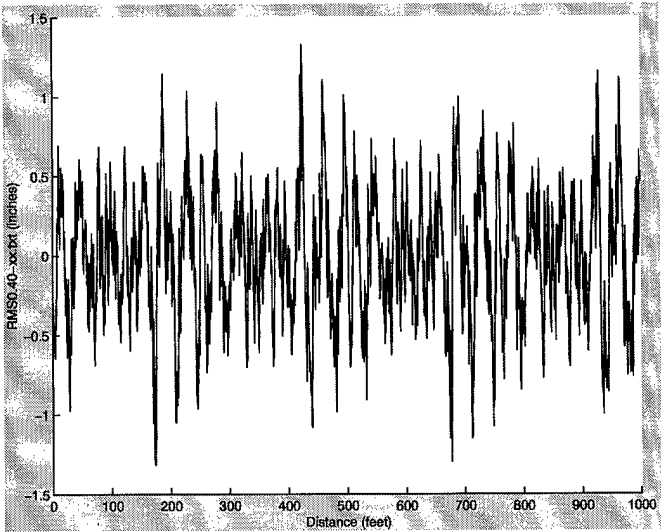


Figure 56 - 0.40" RMS

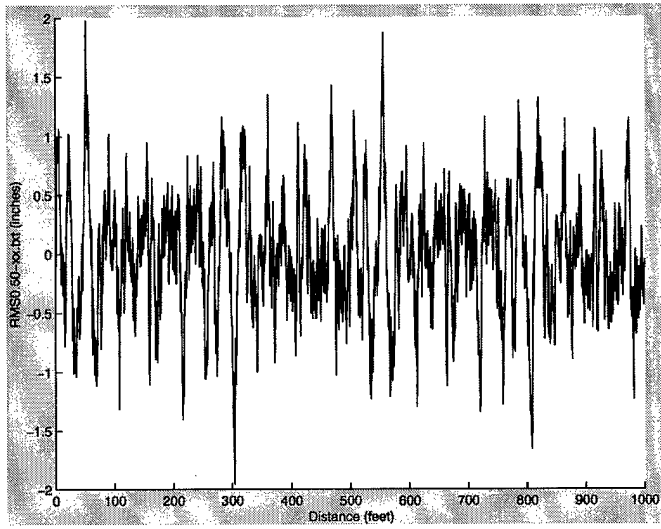


Figure 57 - 0.50" RMS

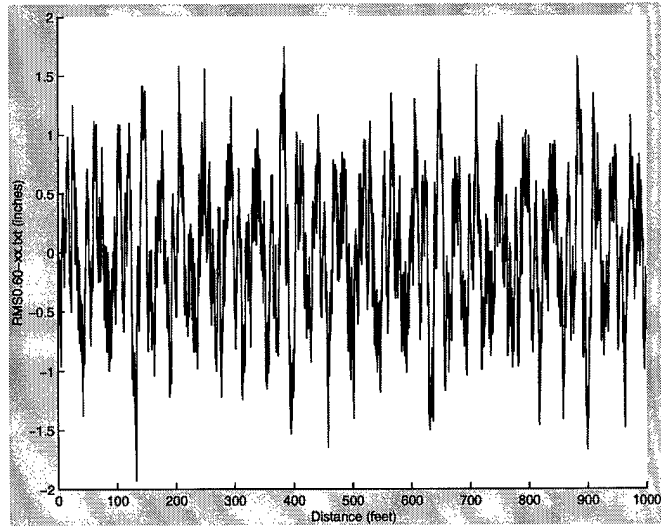


Figure 58 - 0.60" RMS

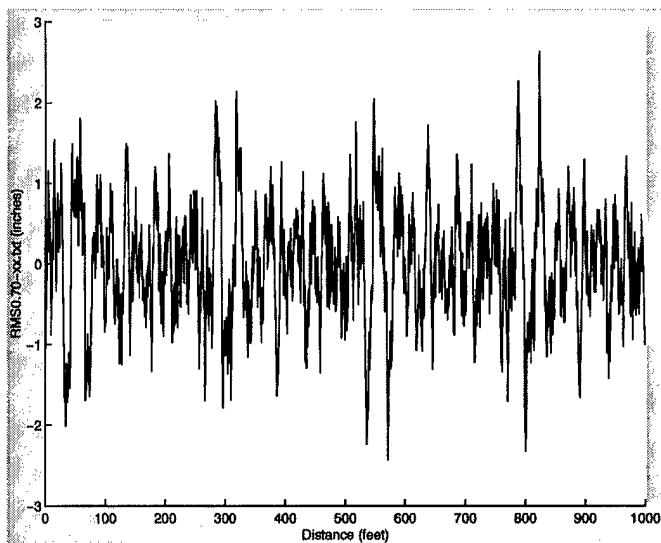


Figure 59 - 0.70" RMS

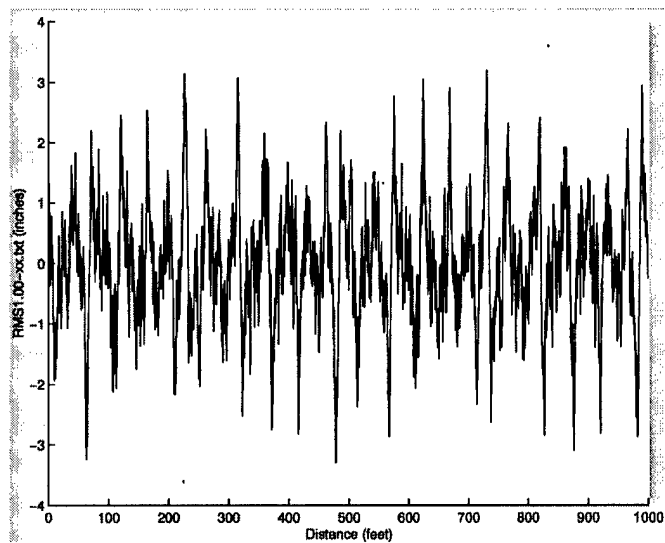


Figure 62 - 1.00" RMS

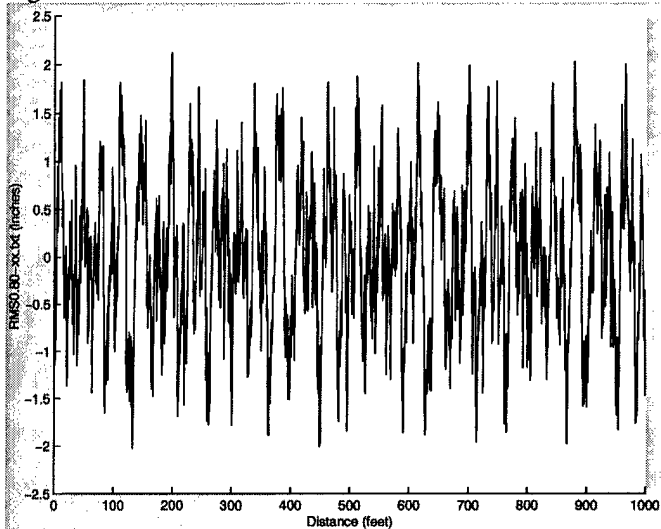


Figure 60 - 0.80" RMS

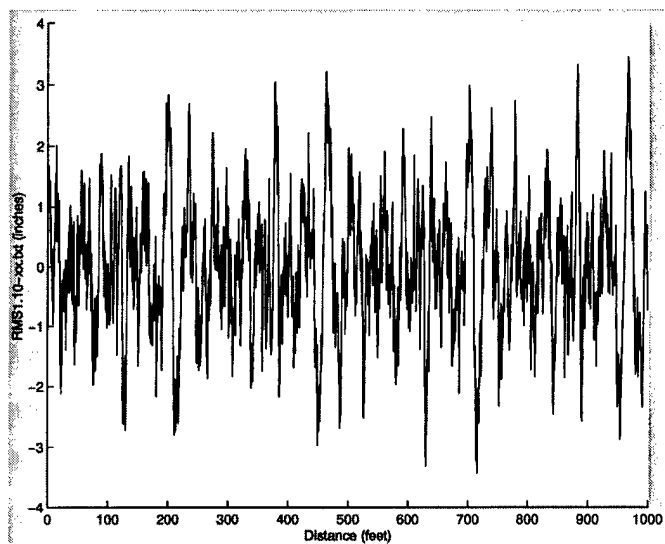


Figure 63 - 1.10" RMS

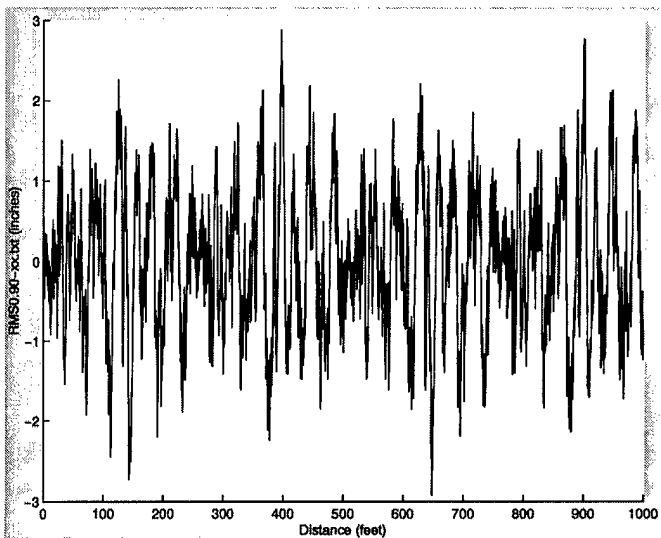


Figure 61 - 0.90" RMS

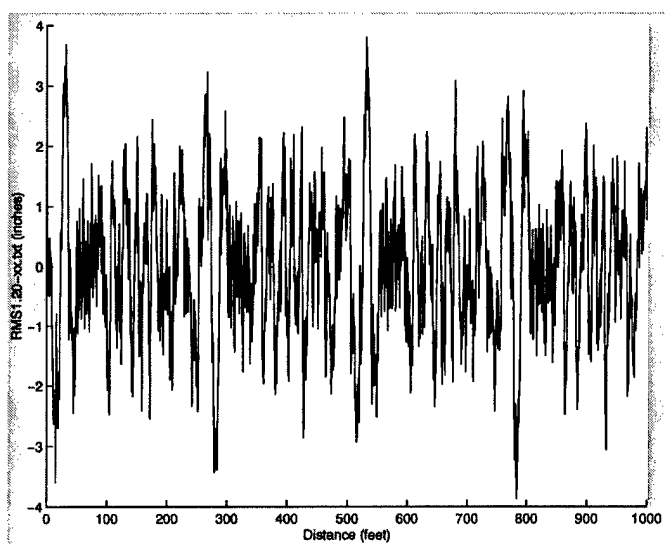


Figure 64 - 1.20" RMS

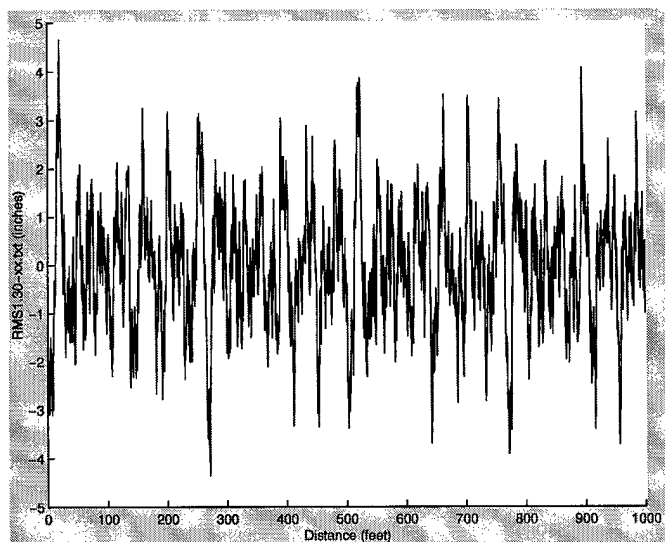


Figure 65 - 1.30" RMS

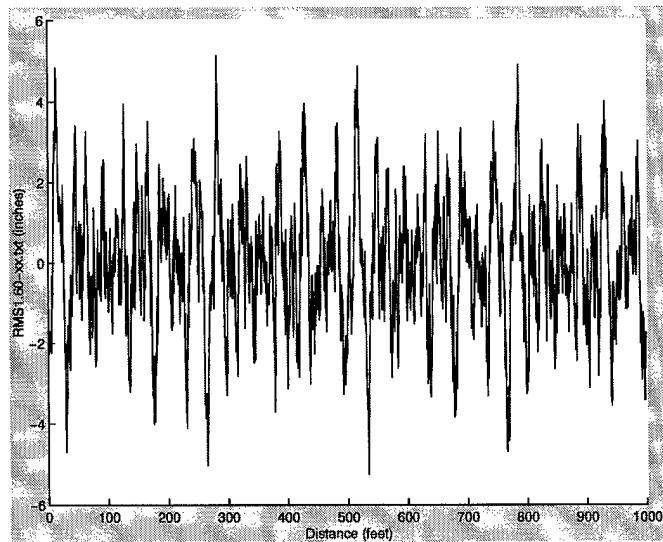


Figure 68 - 1.60" RMS

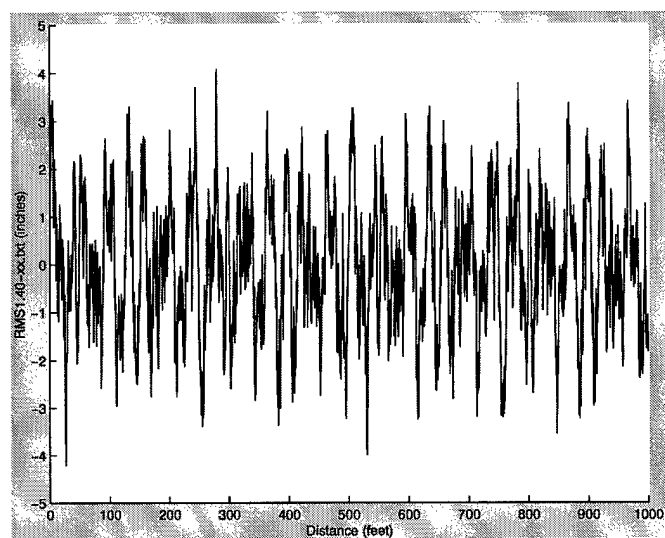


Figure 66 - 1.40" RMS

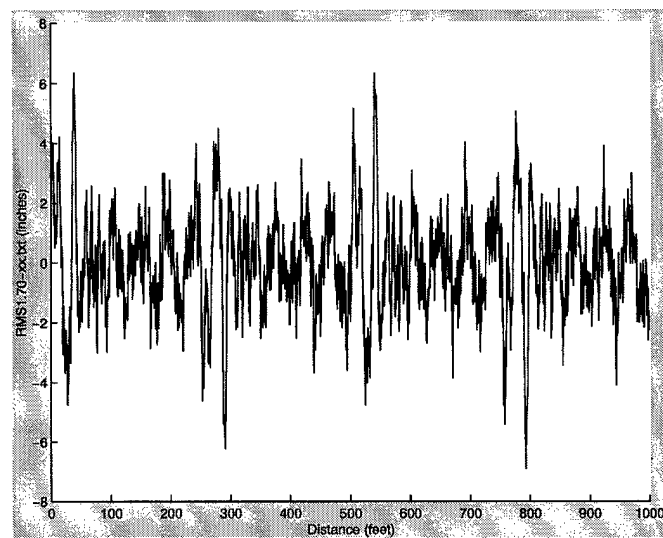


Figure 69 - 1.70" RMS

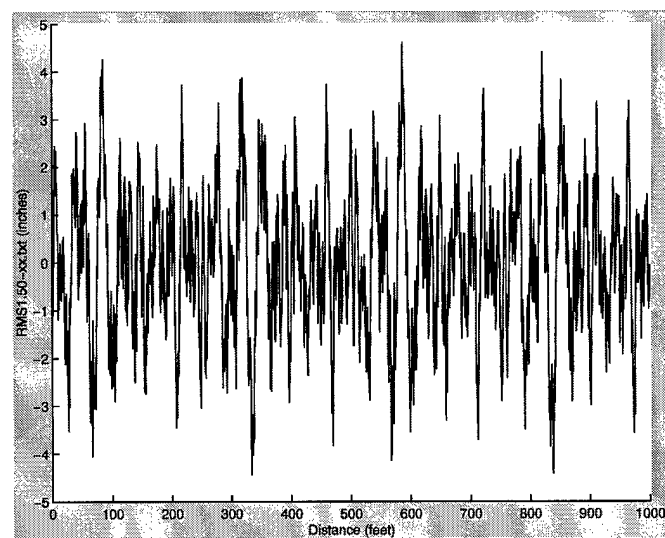


Figure 67 - 1.50" RMS

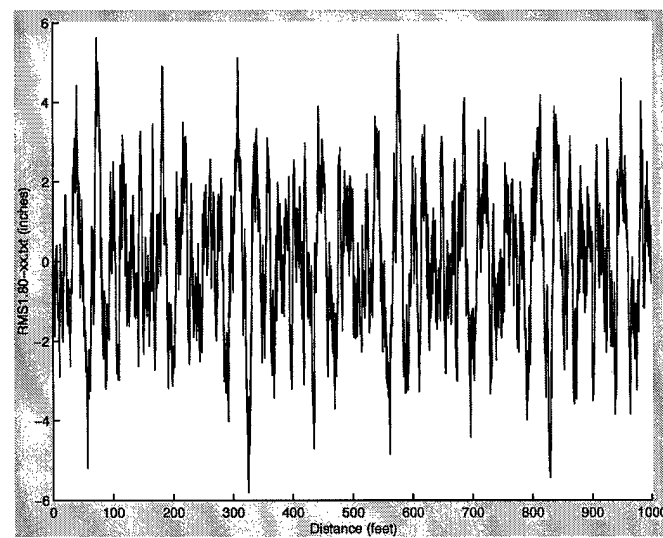


Figure 70 - 1.80" RMS

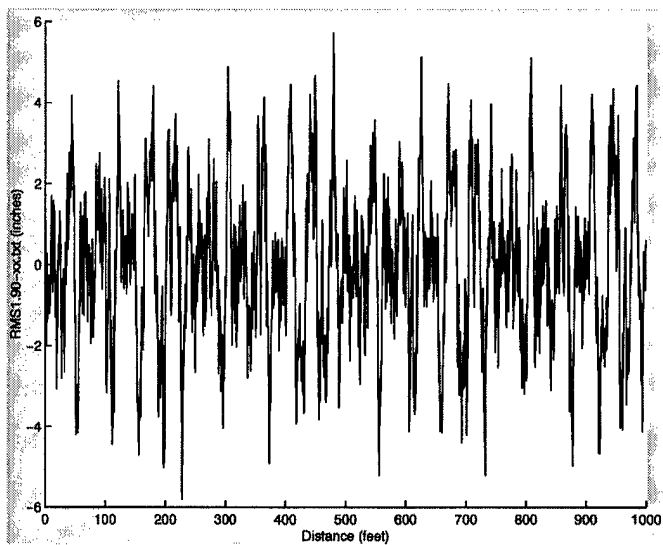


Figure 71 - 1.90" RMS

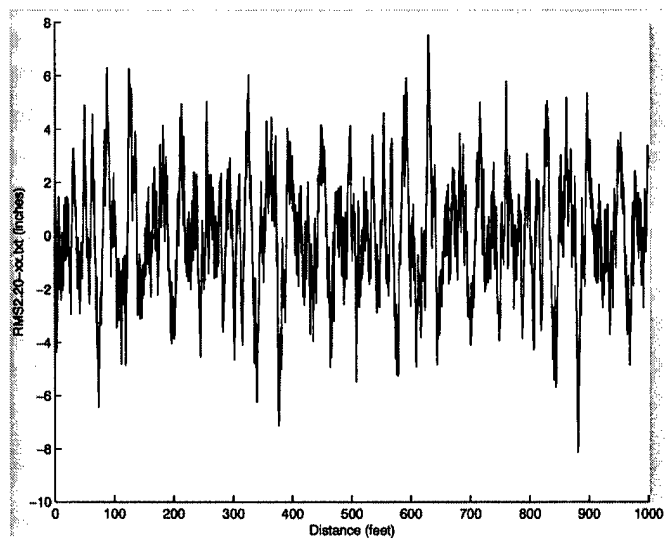


Figure 74 - 2.20" RMS

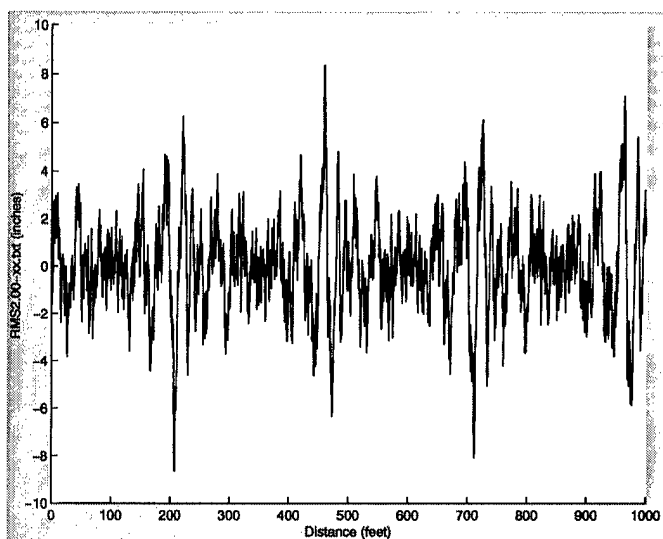


Figure 72 - 2.00" RMS

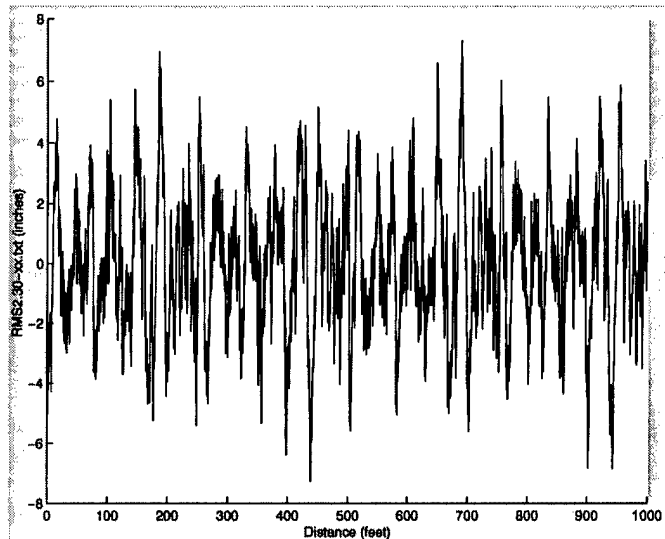


Figure 75 - 2.30" RMS

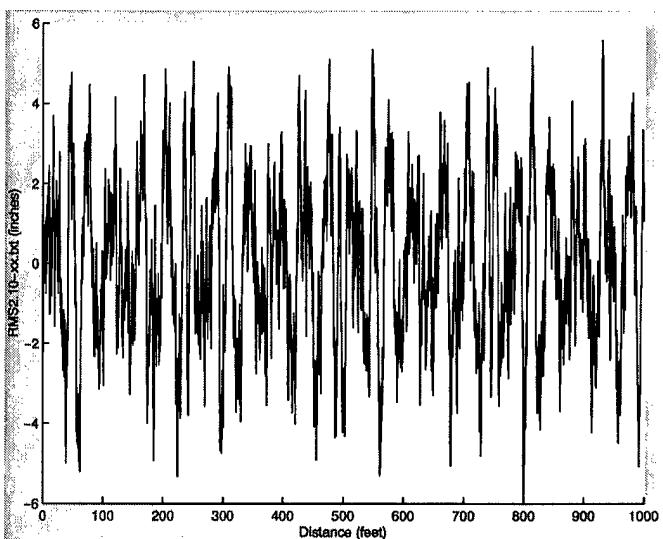


Figure 73 - 2.10" RMS

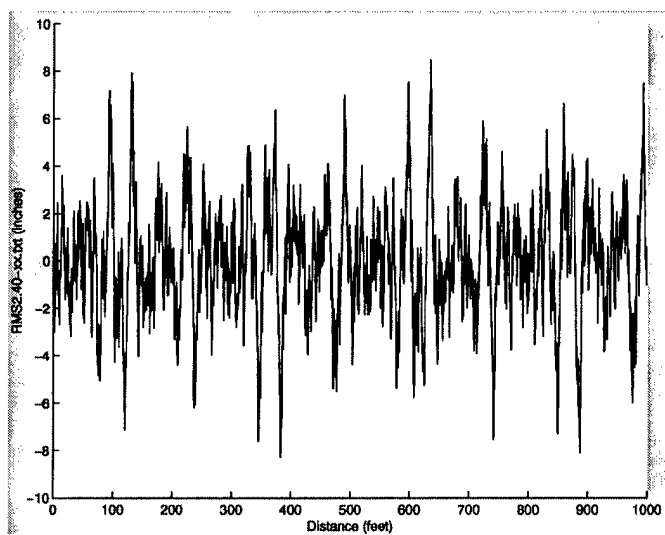


Figure 76 - 2.40" RMS

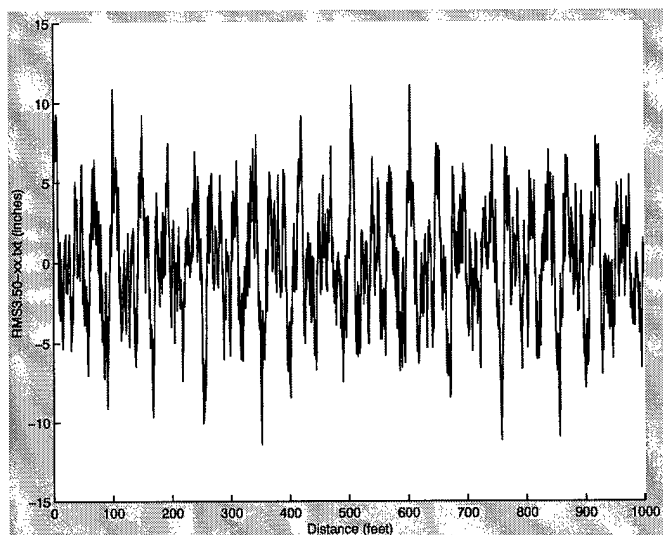


Figure 77 - 2.50" RMS

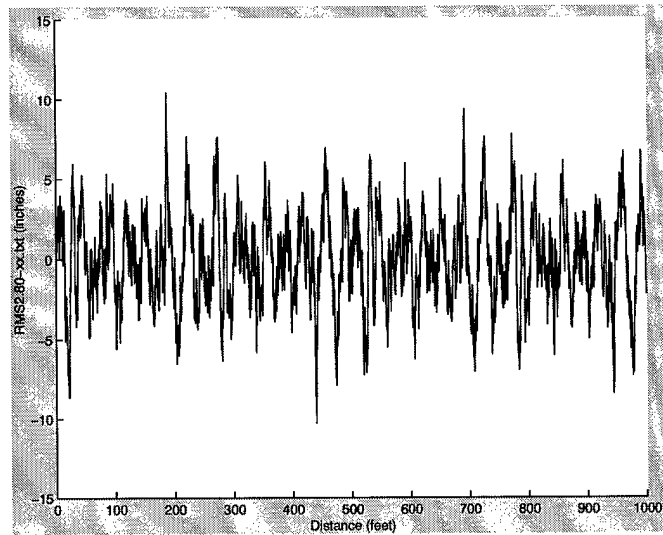


Figure 80 - 2.80" RMS

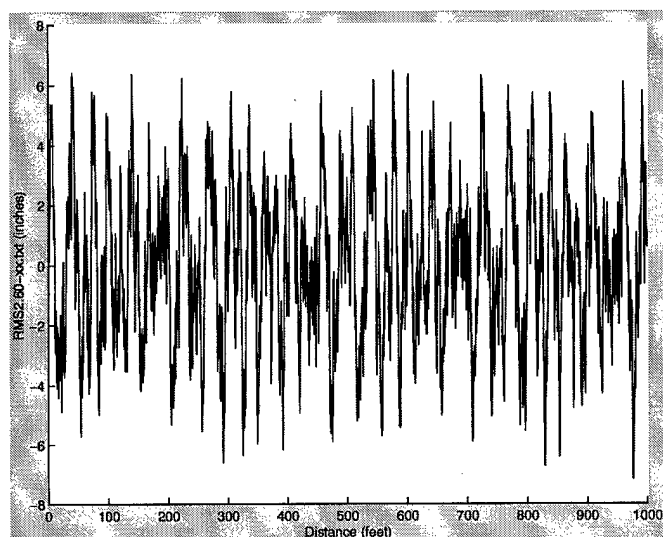


Figure 78 - 2.60" RMS

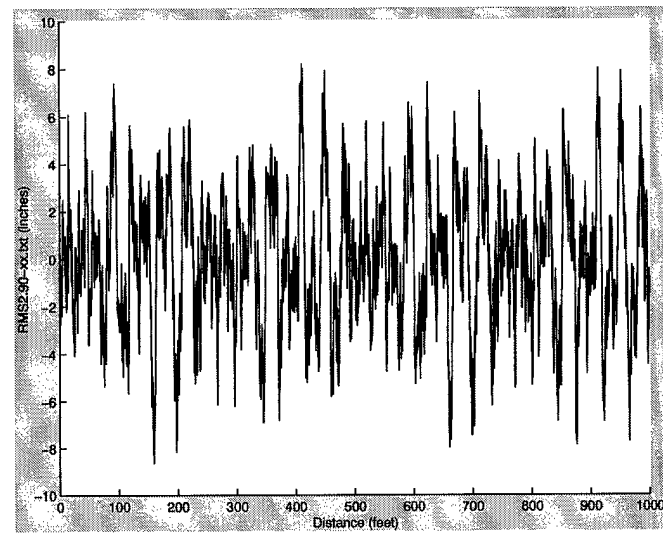


Figure 81 - 2.90" RMS

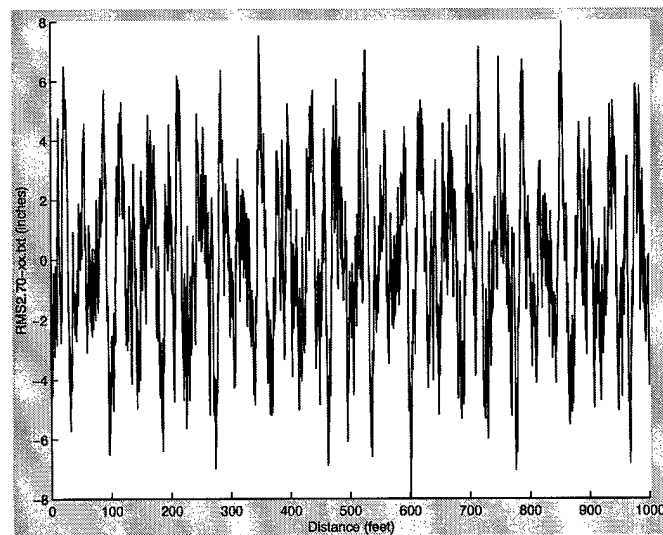


Figure 79 - 2.70" RMS

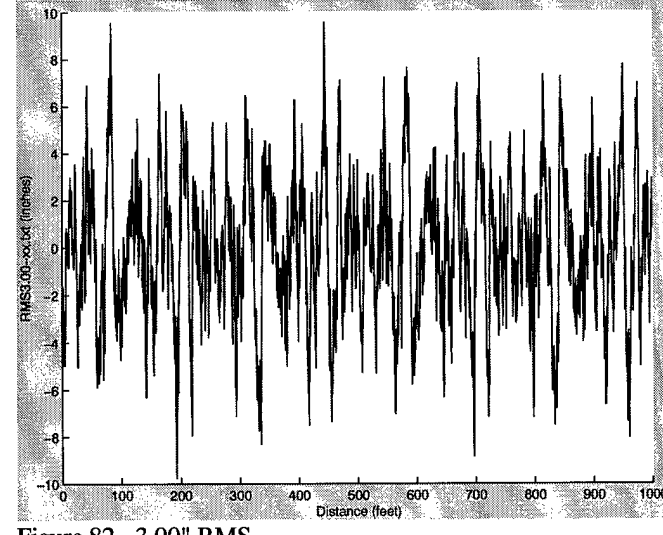


Figure 82 - 3.00" RMS

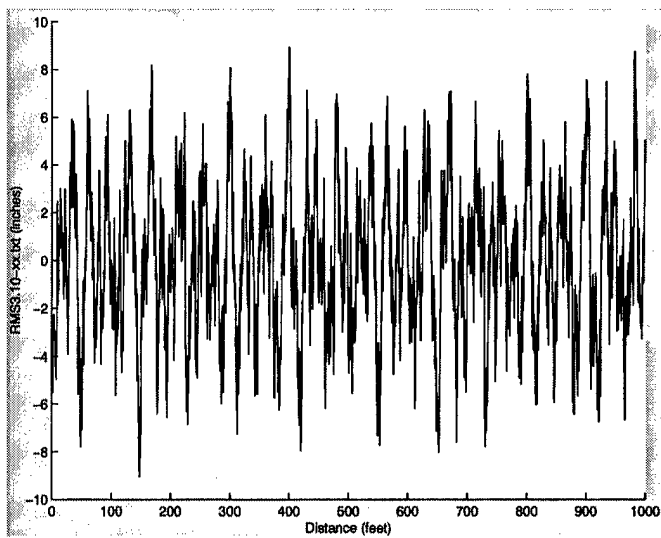


Figure 83 - 3.10" RMS

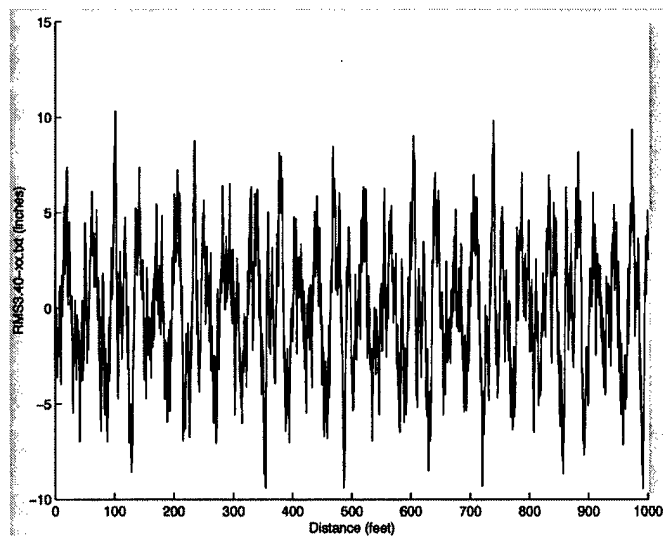


Figure 86 - 3.40" RMS

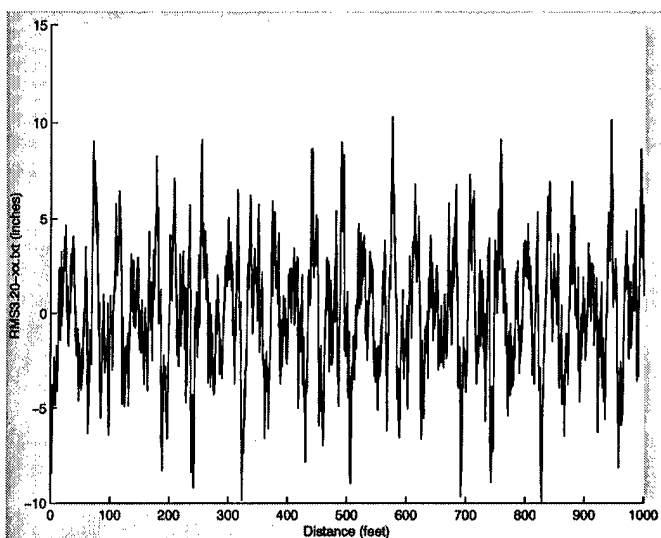


Figure 84 - 3.20" RMS

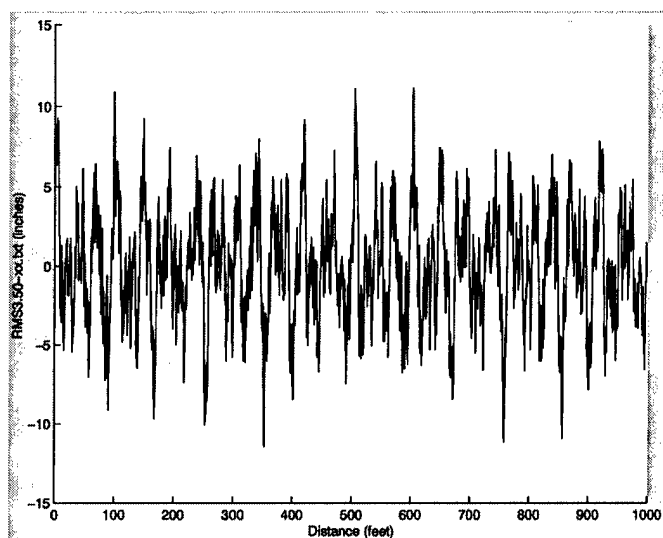


Figure 87 - 3.50" RMS

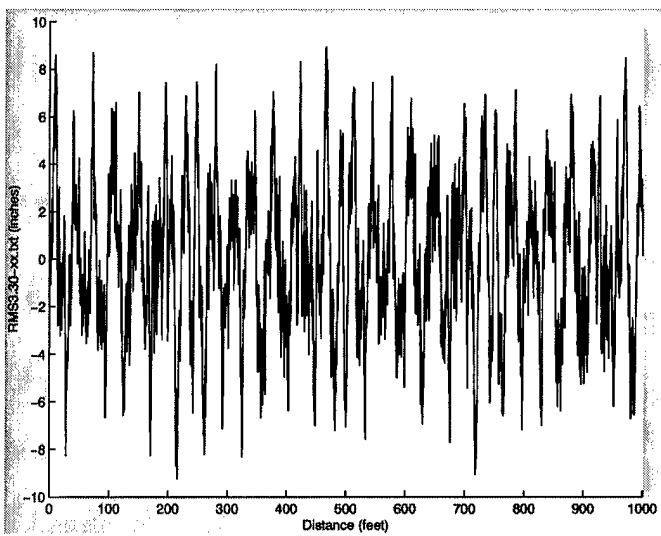


Figure 85 - 3.30" RMS

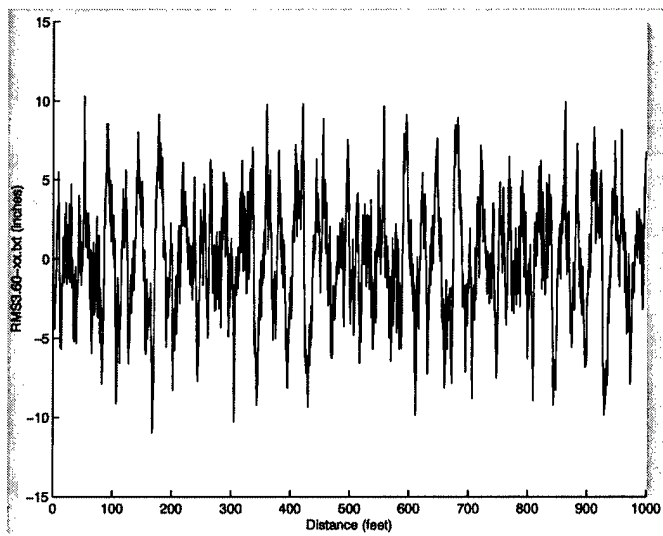


Figure 88 - 3.60" RMS

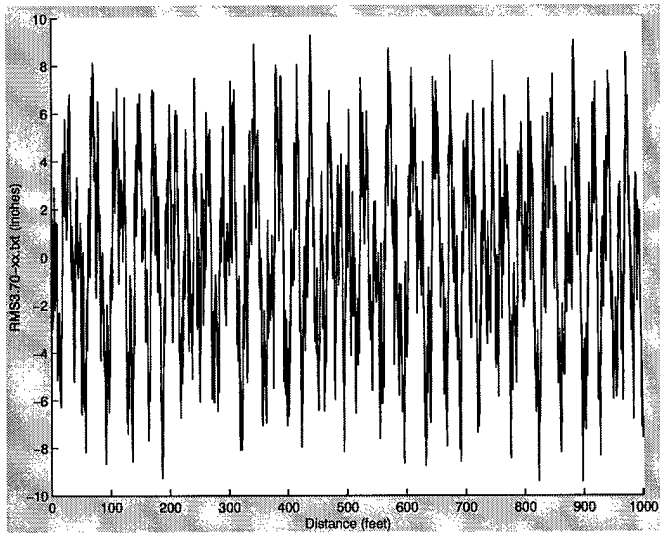


Figure 89 - 3.70" RMS

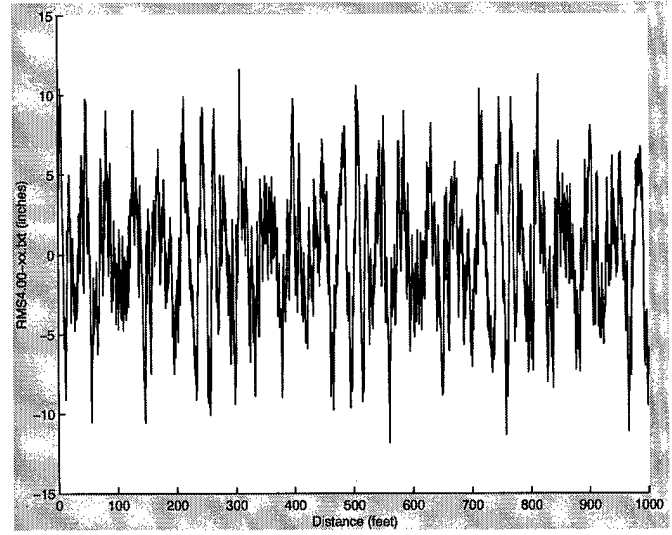


Figure 92 - 4.00" RMS

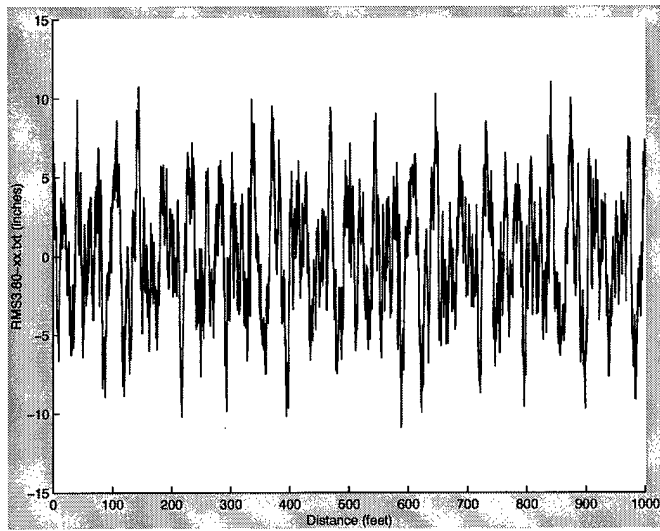


Figure 90 - 3.80" RMS

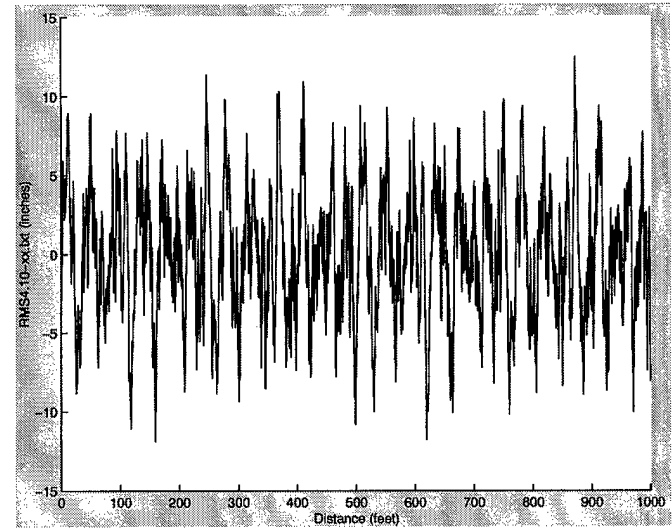


Figure 93 - 4.10" RMS

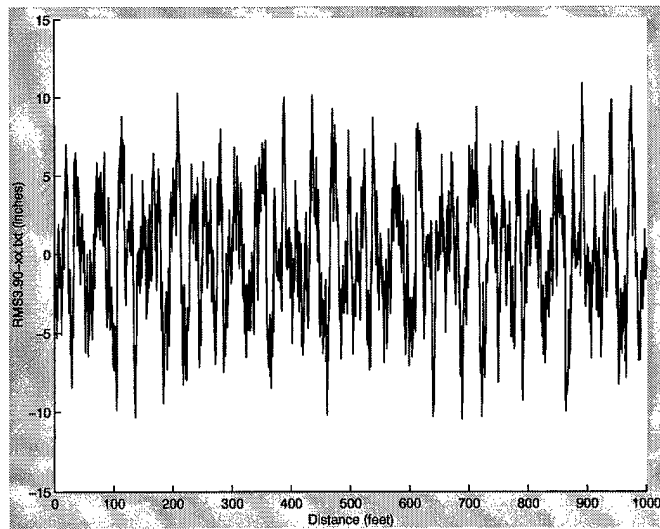


Figure 91 - 3.90" RMS

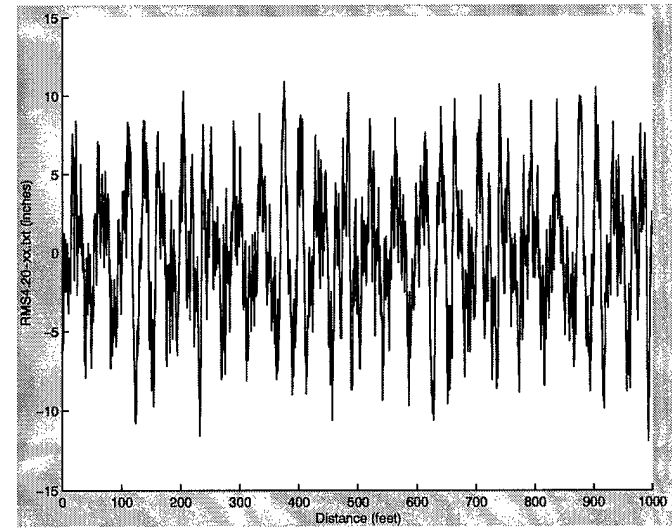


Figure 94 - 4.20" RMS

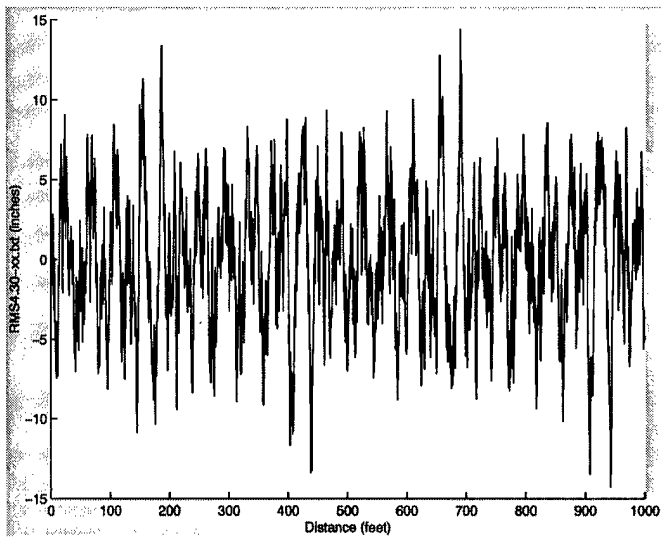


Figure 95 - 4.30" RMS

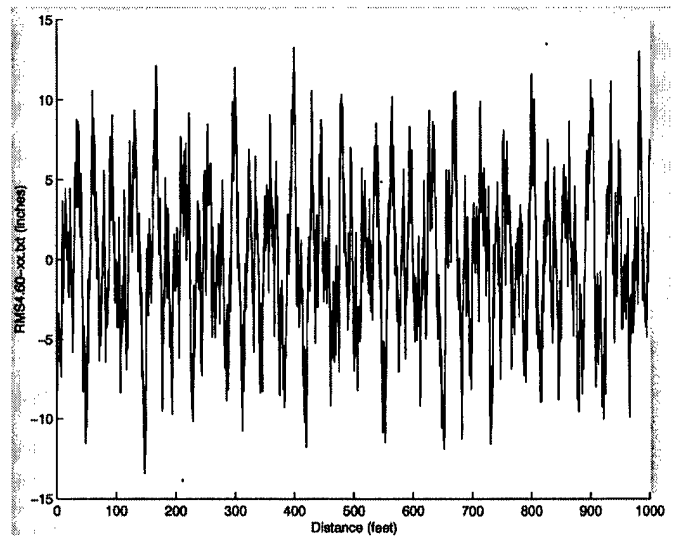


Figure 98 - 4.60" RMS

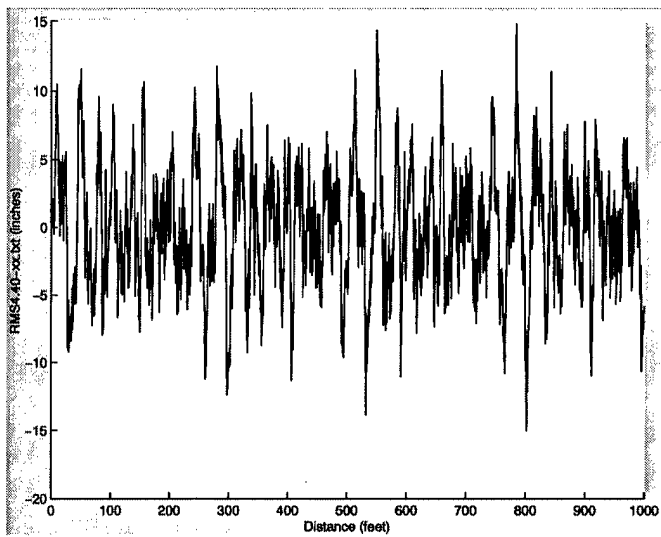


Figure 96 - 4.40" RMS

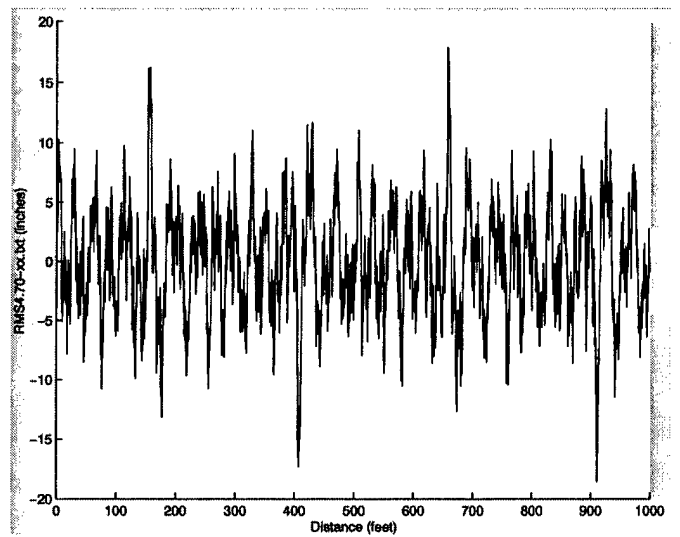


Figure 99 - 4.70" RMS

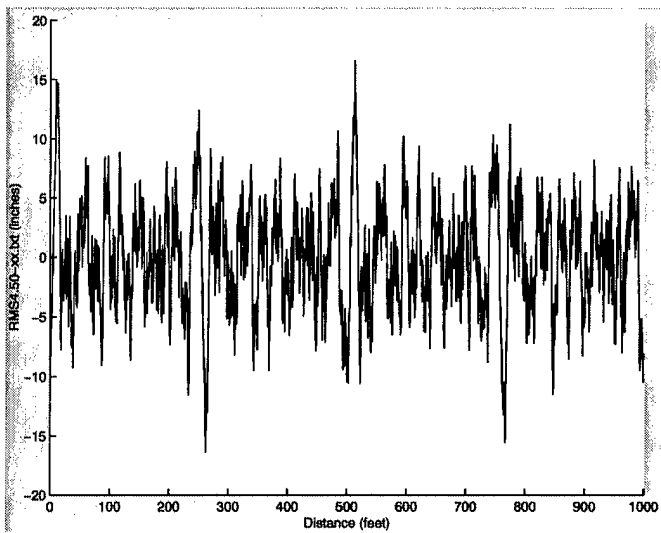


Figure 97 - 4.50" RMS

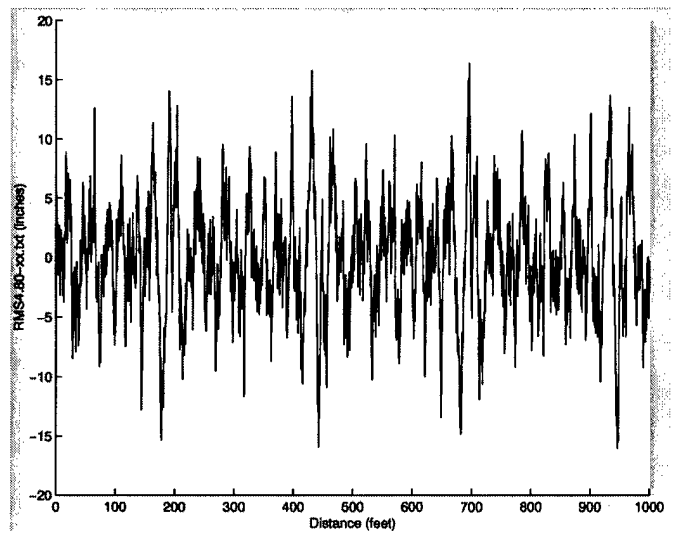


Figure 100 - 4.80" RMS

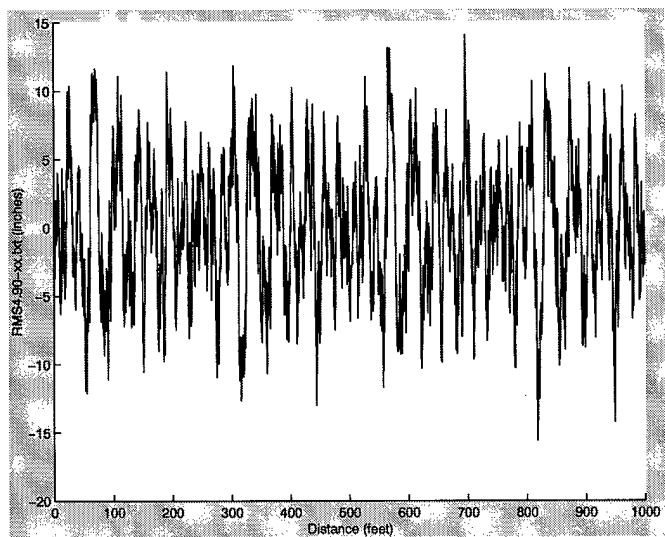


Figure 101 - 4.90" RMS

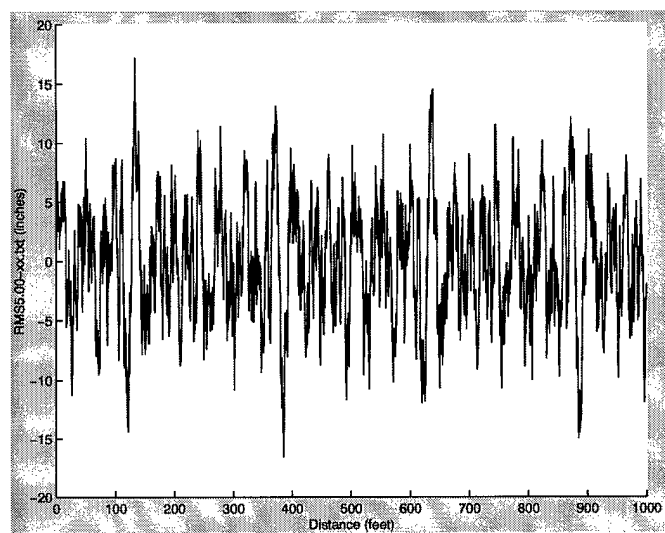


Figure 102 - 5.00" RMS

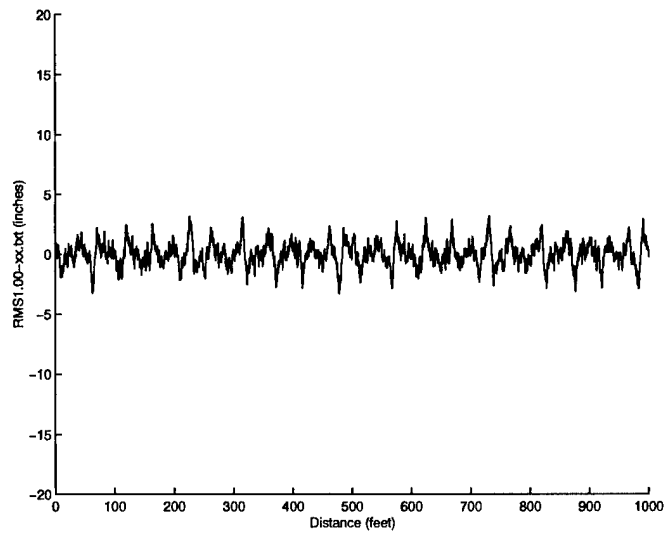


Figure 103 - Scaled 1.00" RMS

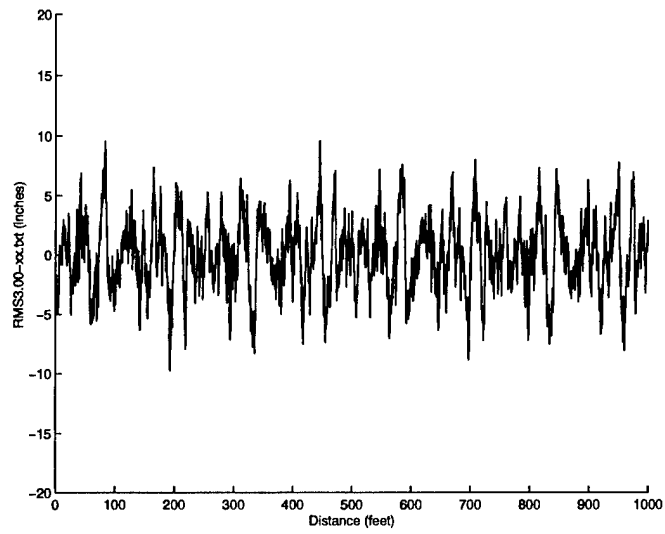


Figure 104 - Scaled 3.00" RMS

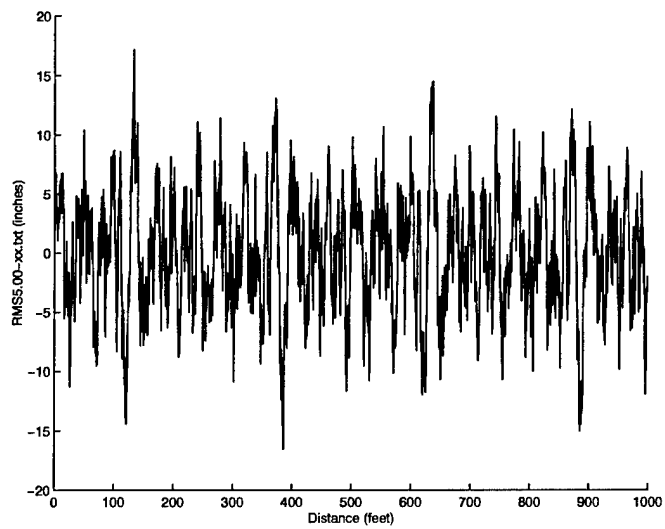


Figure 105 - Scaled 5.00" RMS

3.3 RMS Course Listing Example

3 RMS Course Listing Example

RMS_00-01.txt /magnitude, x in inches	1.218093	0.734245	5.514481	7.332385	2.013225	5.642677	0.637901	2.777471	4.362432	2.624828	3.909815	6.333341	7.403425	6.667419
0.000000	-1.980712	0.931356	4.985956	5.235379	2.323324	6.596493	1.510880	3.637611	3.228989	0.265635	3.345447	-5.763155	-5.472385	1.955772
0.000000	-1.944331	0.472792	5.786179	6.445378	0.420138	8.166833	0.808378	5.650797	1.961673	3.320518	4.068756	6.552206	-6.088272	2.239576
0.000000	-2.233902	0.594984	6.362749	7.902977	0.701498	7.007977	7.007977	5.650797	1.961673	3.320518	4.068756	6.552206	-6.088272	2.239576
4000.	-2.423554	-2.805955	7.514844	8.149946	0.616628	5.828401	5.454334	5.357788	3.381829	4.183205	4.140554	3.901053	-3.830878	1.825737
3.000000	-2.972339	-1.797762	7.424133	5.918765	1.294620	5.172338	4.657194	4.737441	2.959174	3.724572	4.670261	-1.076538	-2.299082	1.170418
1.106454	-4.239255	-4.283610	7.799425	8.773870	0.406534	2.470246	4.531590	4.952950	1.224879	1.535075	4.687024	1.786929	-1.877482	1.754577
1.699111	-4.291829	-5.084014	7.931020	10.987890	1.146749	0.134906	5.301497	4.590536	0.007392	1.164336	4.839762	2.251142	-2.534675	3.404248
4.480530	-3.244792	-6.550317	8.402907	10.927617	1.234897	1.735348	4.287252	3.287488	0.893653	0.501396	4.591369	6.529399	-6.088272	2.239576
0.000000	-5.538589	-5.538589	7.902977	7.902977	0.215770	2.215770	2.215770	6.655792	0.897043	-0.897043	4.914883	-8.500252	-8.500252	3.364720
4.798883	-0.744336	-6.810707	7.805272	13.146028	1.082094	1.144855	2.674105	2.718176	1.105621	-1.005621	-2.437960	6.520156	-5.07172	1.862893
4.353987	-6.360547	-9.975005	13.519191	-1.206025	0.209765	0.813537	4.791036	1.747448	1.241701	3.599292	3.210716	-6.043896	5.686219	1.825737
4.490341	-5.762594	-5.691117	8.535547	-0.932410	0.903626	0.349904	5.724641	4.740494	-1.812795	-5.521802	1.730841	-1.684505	5.340269	1.754577
6.719324	-3.486668	-4.937887	8.609987	13.687142	-1.838911	3.359048	2.384735	7.875455	0.143024	0.649176	1.595334	-4.422205	7.624617	1.754577
6.079264	-4.240444	-5.084863	8.681891	14.564068	-4.241873	3.6170537	1.663350	2.205353	0.893653	0.501396	4.591369	-6.043896	5.686219	1.825737
3.550467	-3.080462	-6.316228	4.485317	14.701029	-3.096294	1.815674	0.056466	2.538715	0.776313	0.293586	0.607544	4.608038	-5.636799	1.825737
2.852696	-1.753535	-6.812398	1.988532	13.273808	-2.002130	2.859728	-8.864389	3.704792	2.488959	-2.650609	-6.897240	6.032337	-6.742620	2.584556
3.962392	-0.877995	-7.501085	2.075987	-3.120004	1.581011	-4.290983	4.362707	3.567192	-2.453781	-5.379957	7.624507	-2.474602	8.408453	1.754577
4.545118	0.334500	-4.412333	7.700249	10.726241	-4.299452	2.829540	-5.404745	6.292329	2.645350	-3.955455	4.708037	-0.367619	0.037292	1.754577
3.363544	1.639917	-6.435994	1.894969	10.812383	-2.701340	4.638022	-6.724727	3.777796	3.777796	-2.458680	4.528872	-4.528872	0.037292	1.754577
2.796773	2.504661	-1.846461	1.907253	7.710956	-0.147488	1.557459	3.731209	4.026465	-5.896608	2.615990	-0.433191	5.228420	-3.788531	1.412656
3.204974	2.027660	-8.591745	0.351256	-2.268108	1.169068	5.714614	-4.652707	3.386198	-4.848448	-3.298928	1.772500	7.188200	2.813358	0.052300
2.877470	3.946624	-8.476425	-0.281608	5.935515	2.215352	5.551354	-3.209787	3.308754	5.019664	3.426963	9.547658	3.667335	7.572274	1.754577
3.752613	4.778104	-8.003066	1.097250	5.802122	2.395864	7.275443	-0.707080	2.433054	5.069990	5.006858	7.735983	2.797564	6.088252	1.754577
2.955834	4.857445	-8.410122	-0.846478	8.1828014	-8.187501	9.395972	-5.502972	1.217636	0.094217	0.094217	7.700917	2.505681	1.754577	1.754577
1.066049	1.066049	-4.987436	1.066049	1.066049	-2.250768	2.250768	2.250768	2.250768	2.250768	2.250768	2.250768	2.250768	2.250768	2.250768
9.967376	4.383423	-9.495503	1.534464	7.212149	9.912190	4.212966	-5.957680	1.563290	3.860584	4.017358	0.037190	5.563337	2.664594	4.183247
2.261646	4.575338	-7.530672	3.416423	8.564122	-9.957703	2.849841	-4.916103	-4.618922	-2.099348	0.223741	4.662683	6.251255	4.839692	5.139717
2.588638	7.454997	-9.813511	-4.961268	8.990516	-9.964419	5.188187	-3.908908	0.400773	5.005110	-1.009438	4.605554	5.917860	3.949845	3.942888
3.311203	1.280263	-9.065318	-4.063609	8.903190	-9.936910	4.031012	-3.913769	0.210156	3.759035	1.958155	0.907743	4.101641	0.989645	0.759931
3.476291	2.359308	-9.353472	-2.825494	8.217043	-9.097887	4.688874	-4.345850	4.791611	4.612803	3.968624	7.993039	3.352852	7.799452	1.754577
2.747888	1.086630	-9.353472	-2.825494	8.217043	-9.097887	4.688874	-4.345850	4.791611	4.612803	3.968624	7.993039	3.352852	7.799452	1.754577
4.087676	4.087676	-7.555832	-8.290348	10.05819	-5.504356	8.815480	-1.903586	7.829521	10.835414	5.118635	10.763260	5.097309	6.796507	1.076020
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3.341127	3.384842	-2.800209	-3.912695	7.616130	-5.474834	-0.684960	-3.751187	3.282883	4.727890	1.725093	7.472548	3.674578	1.080550	3.151259
5.774405	2.924486	0.579647	-5.080311	8.592091	-5.532805	-0.180854	-4.399613	4.428938	4.289398	1.831360	9.841074	1.527614	-0.006393	1.352593
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5.418979	2.168746	2.168746	4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166	-4.854166
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4.888689	-1.029441	-8.056505	-6.365192	-6.160361	-6.285085	-2.390767	-3.930929	-1.342603	-1.077755	-1.080233	-1.687180	-5.051173	-3.178906	-1.709083
7.243310	-1.784782	-6.740629	-6.559994	-5.102392	-8.414338	-4.090655	-9.017267	-1.085569	-1.045598	-2.376847	-3.465745	-5.942301	-3.303853	-3.663993
8.763460	-1.443641	-9.380998	-7.147336	-2.569238	-6.595333	-3.025126	-1.127686	-1.165419	-1.326014	-1.975141	-5.348234	-4.256233	-1.777465	-0.009904
9.818723	-0.130545	-1.371610	-1.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479	-4.971479
7.848501	-1.562943	-7.445835	-3.089798	-2.261872	-7.481308	-2.707850	-10.668150	-4.257189	-2.022886	-2.646805	-6.393849	-0.171628	-4.798410	-3.297846
6.099612	-1.626481	-7.660292	-2.649797	-4.447179	-8.254118	-2.493968	-9.935296	-8.293431	-0.387013	-0.497668	-5.687342	-1.079010	-5.185132	-4.723999
4.455926	-2.003815	-7.188672	-2.531580	-4.823528	-7.648586	-3.008488	-9.471631	-4.106607	-0.941290	-0.674052	-7.718355	-2.188021	-5.884234	-4.380611
4.585274	-2.925875	-6.236065	-2.237169	-5.922203	-3.001365	-0.001365	-2.136647	-6.443526	-1.299748	-1.286507	-6.714895	-3.745656	-5.124645	-4.231691
5.201468	-2.546681	-7.258272	-2.908197	-8.435052	-5.846866	-2.442341	-2.289840	-4.388401	-0.050190	-3.116228	-7.863680	-3.562421	-7.999021	-4.702971
6.307828	-1.255358	-7.832101	-2.122749	-5.103776	-6.843296	-3.266359	-4.311112	-4.999807	-6.333203	-3.066252	-8.543776	-1.640036	-0.007828	-4.055941
2.923234	-0.974465	-2.144465	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265
4.592339	-1.823578	-7.314294	-4.181515	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265	-4.516265
4.215044	-1.482674	-7.958632	-2.549571	-7.126266	-4.512223	-4.721427	-5.689163	-5.110988	-4.969143	-5.393854	-5.045183	-2.670753	-5.107112	-5.568574
2.060739														

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