# MONITORING MEASURING REPEATABILITY
# AT RADIATED EMISSIONS TESTING FACILITIES

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## ABSTRACT

Maintaining adequate measuring accuracy and repeatability at radiated emissions testing facilities (e.g., open field sites and semi-anechoic chambers) is necessary to maintain credibility. Although catastrophic failures are usually readily apparent, slow changes to measurement accuracy or minor failures are difficult to detect. Annual or semi-annual preventative maintenance is necessary to insure accuracy, but cannot insure repeatability (i.e., continued accuracy) between maintenance periods. A method is described applying statistical quality control to weekly measurements of a standard, multifrequency source to produce a running control chart of EMI measuring system repeatability.

## INTRODUCTION

EMI testing facilities must continually insure a high degree of confidence in measuring accuracy and repeatability. Catastrophic failures are usually readily apparent, but slow changes in measuring accuracy are difficult to detect without frequent monitoring. Periodic equipment preventative maintenance and calibration, and site attenuation measurements are essential, but may not be sufficient to maintain adequate confidence unless performed more frequently than is practical.

Challenges to radiated emissions measurement accuracy seem to be intrinsic to EMI testing. These challenges usually come from the users or customers of test facilities, especially if test results are not favorable. Many challenges prove to be undeserved, yet valuable time must be spent answering them.

A method for frequent, periodic verification of measuring consistency, producing a control chart showing measurement variations, is described. Facility time spent to collect and reduce verification data is less than 1 hour per week. This method works with regularly scheduled preventative maintenance to maintain confidence in EMI test results at an adequate level.

## TEST PROCEDURE

To insure measuring consistency, the RF emissions from a consistent, highly reliable source are measured. A compact, battery operated comb generator (CG) was constructed (see Figure 1). This device uses ECL circuitry to produce a short output pulse with useful harmonics in the 30 to 700MHz range (see Figure 2), at levels near the FCC Class B limits. The fundamental frequency can be either 10 or 30 MHz, chosen by selection of the oscillator crystal. A short (18.2 cm) vertical antenna was connected directly to the comb generator's output connector, and a small panel meter shows the status of the internal battery.

A formal test procedure was written to minimize process variability. A flowchart of this procedure is shown in Figure 3. Each Monday morning, prior to any formal testing, the technician on duty proceeds through a checklist of visual inspections, then measures CG emissions at 9 specified frequencies. These frequencies were chosen to be "in the clear" on the open field site (no adjacent or coincident extraneous signals), and to provide a test of both broadband receiving antennas normally used. Data are stored on disc for future reference, and archival copies are kept.

## DATA REDUCTION

A computer program was written to perform data storage, analysis, and reporting. A general purpose spreadsheet program was first evaluated for this application, but the custom program was quicker and easier to use. The time required to create this program has proven to be well justified by its frequent use and simplicity.

Weekly data have been aquired since February 1986. Since up to 75 weeks of data can be retained by the program's data file, at least one annual preventive maintenance and calibration is included in the current data file. These serve as confidence "check points" if the weekly repeatability test results are consistent within the expected variation before and after preventative maintenance and calibration.

The emissions at different frequencies are not necessarily of the same amplitude, so all data are first normalized by subtracting the average emissions at each frequency for the first 20 data sets (weeks). (Subtraction was chosen instead of division to normalize the data because the measured data units are dBuV/m, and subtraction in decibels is equivalent to division in absolute terms. The number of data sets was chosen arbitrarily.)

The average of the 9 normalized measurements for each week is calculated, then plotted on the control chart. A simple average of the set's unnormalized data would have no physical relevance since the harmonic emission amplitudes from the comb generator are all different, while the average of a normalized data set is essentially the <u>normalized</u> <u>average</u> <u>emission</u> for that week.

An "X-bar & R" control chart (see Figure 4) was chosen to track the movement of the weekly normalized average emission [1] about its long-term average. This average (sometimes refered to as the "grand" or "double" average) and standard deviation were calculated over the first 20 data sets (weeks). Upper and lower control limits were computed from this "double" average plus and minus 3 standard deviations. The first 20 data sets have and will continue to be retained, thus any long-term trends will become apparent. As an additional feature, the program automatically scales the vertical scale to comfortably accommodate the control limits and weekly normalized average emissions.



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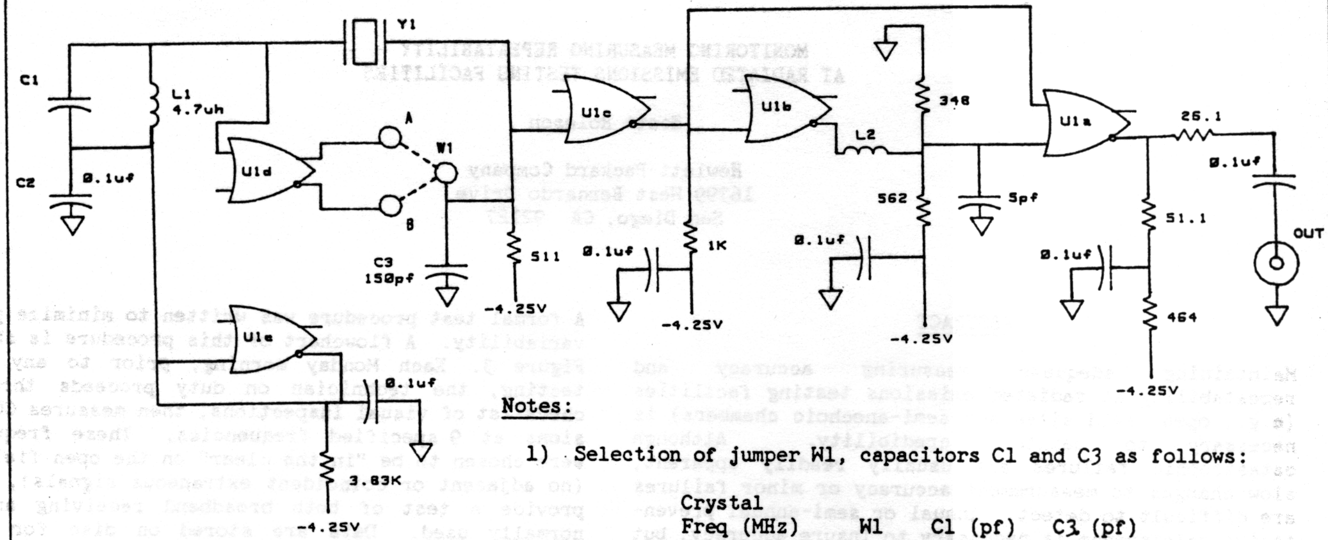


Notes:

1) Selection of jumper W1, capacitors C1 and C3 as follows:

| Crystal Freq (MHz) | W1 | C1 (pf) | C3 (pf) |
|---|---|---|---|
| 10 | A | 47 | 150 |
| 30 | B | 27 | 100+47 |

2) C3: For 30MHz, C3 is a 100pf capacitor in parallel with a 47pf capacitor, where the 47pf capacitor is located at the driving end of the crystal, Y1.

3) L2: Five turns #26 enameled wire on a Micrometals T25-12 toroidal core, or equivalent.

4) U1: 100102 ECL integrated circuit. Pins 6 & 7 are grounded. Pins 1 & 8 are connected to -4.25VDC. All unused pins are open.

*Figure 1. The comb generator uses a single 100K-series ECL IC.*

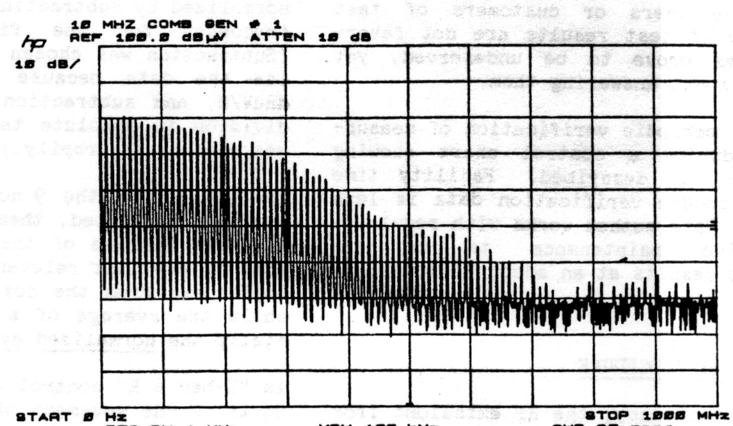


*Figure 2. The comb generator produces useful harmonics into the UHF range.*

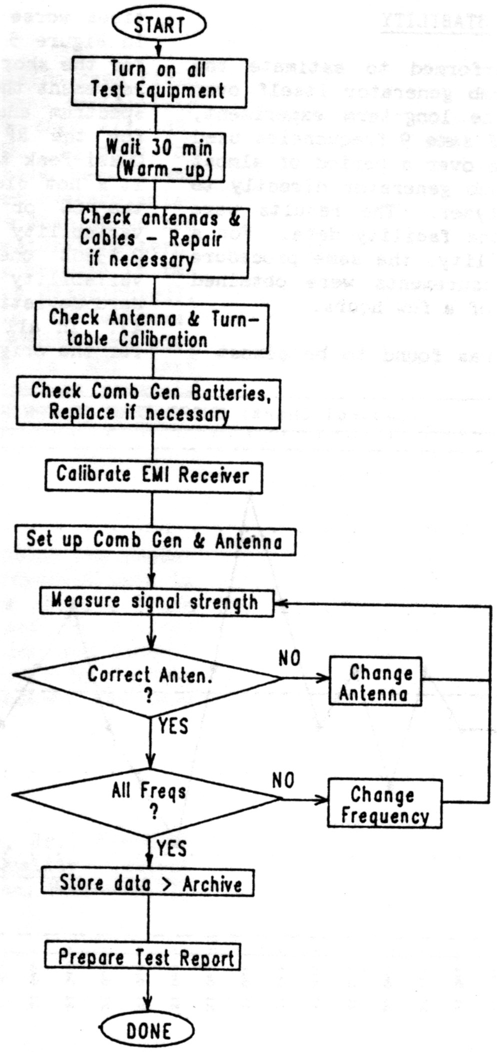


*Figure 3. To reduce variability, a "Repeatability Test Procedure" was written.*

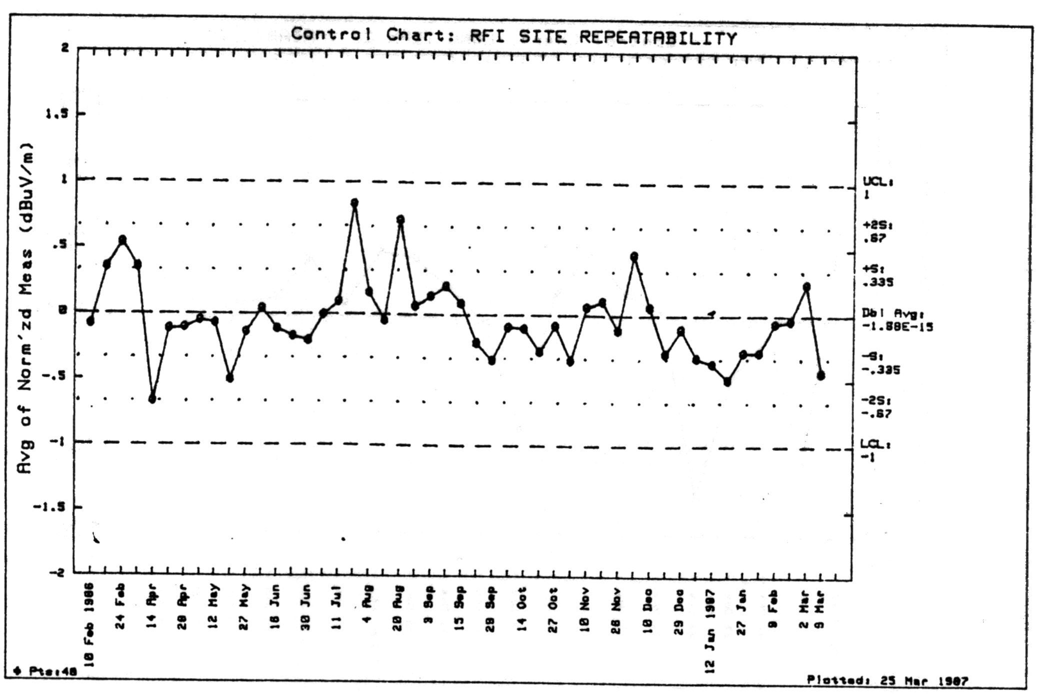


*Figure 4. The normalized average emission from week to week is tracked on a control chart.*

COMB GENERATOR STABILITY

Separate experiments were performed to estimate the maximum variability of the comb generator itself over long and short-terms. For the long-term experiment, twenty sets of measurements of same 9 frequencies used in the facility test were made over a period of almost 6 months by connecting the comb generator directly to the input of a spectrum analyzer. The results were analyzed in the same way as the facility data. For a short-term estimate of variability, the same procedure was used, but 20 sets of measurements were obtained consecutively within a period of a few hours.

The long-term CG variability was found to be almost 9 times worse than its short-term variability, as shown in Figure 5 for the long-term experiment and Figure 6 for the short-term experiment. These data more exactly represent the variability of the comb generator and the spectrum analyzer, without the other components used for the RF emissions measurements (RF Preselector, Quasi-Peak Adapter, cables, antennas, etc.). Although it's not clear how much of the variability is due to the CG or spectrum analyzer individually, the CG variability is no greater than this. In any case, the 0.138dB one standard deviation for the long-term variability is still better than the .335dB one standard deviation for the facility variability (see Figure 4). In all cases the variability is quite acceptable for the original purpose.

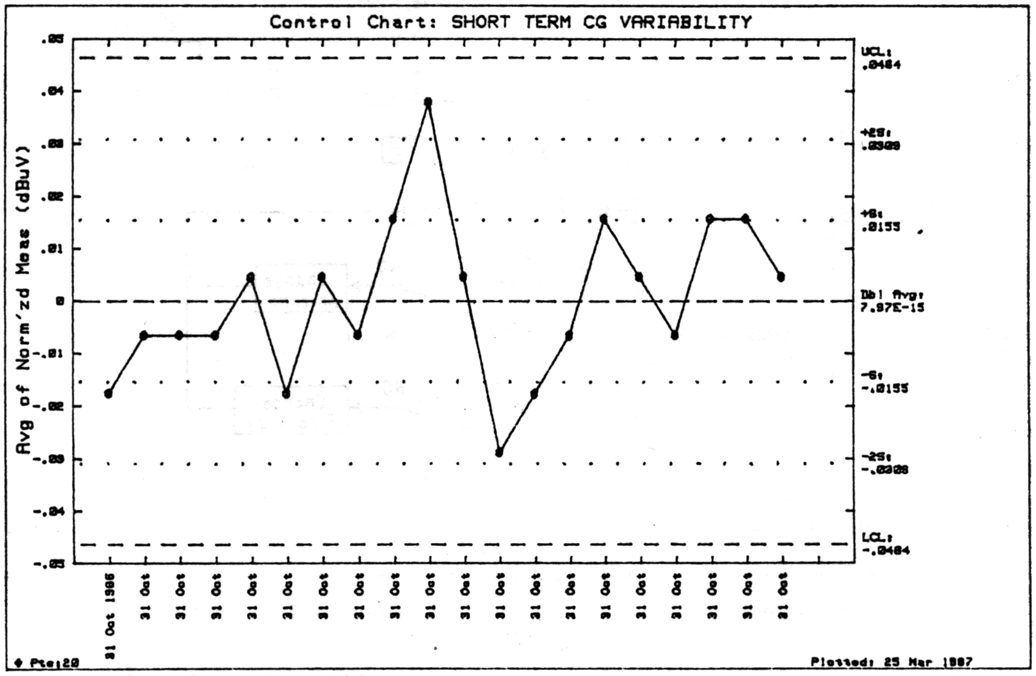


*Figure 5. The long-term variability of the comb generator was evaluated over a 6-month period.*

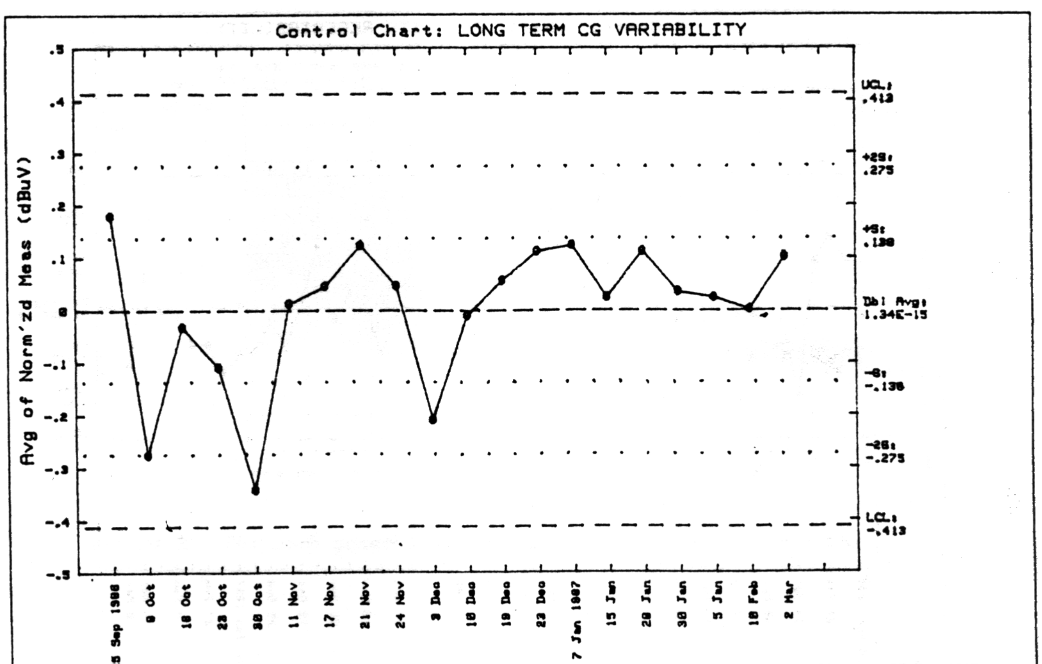


*Figure 6. Short-term comb generator variability was evaluated over a few hours.*

## CONCLUSIONS

Used at Hewlett-Packard's San Diego Division open field site since the Spring of 1986, measurement variability has been found to consistently be less than +/- 1dB, and usually less than about +/- 0.34dB. To date, no verified "out-of-control" conditions have been seen, although the tendency for the normalized average emission to be below the double average more than above has been detected (this is known as an "unnatural pattern" in statistical quality control parlance because it implies that the data may not be normally distributed). The source of this possible anomaly is unknown. Display of the weekly-updated control charts has significantly increased user confidence in EMI test results and has reduced the time required to separate product and measuring system variability found in those results.

## ACKNOWLEDGEMENTS

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## REFERENCE

[1] Bicking, C. A. and Frank M. Gryna, Jr., "Process Control by Statistical Methods", Quality Control Handbook, ed. by Juran, Gryna, & Bingham, McGraw-Hill, 1979, pp. 23-8 to 23-9.