Measurement Anomalies Associated with the “41 Inch Rod” antenna when used in Shielded Enclosures

Steve Jensen July 17, 2000
Steve Jensen Consultants Inc.

Background

MIL-STD-462 (now MIL-STD-461E), DO-160C/D, various proprietary EMC standards and certain Harmonized EC standards require measurement of radiated emissions using the so-called "41 inch rod" antenna. The applicable frequency range of measurement using this antenna is 14 kHz to 30 MHz. The antenna consists of a 41-inch collapsible rod mounted over a ground plane that is about an 18-inch square. This plane is in turn to be electrically bonded to the copper ground plane test bench using a copper strap whose width equals the width of the antenna ground plane and is 1 meter in length. The antenna and it's associated ground plane is usually physically supported at a height of 1 meter above the screen room floor using a wooden or other non-conductive tripod support. Over the years, many EMC tests, regardless of the nature of the test sample, have exhibited an apparent "peaking" of the test emissions usually in the 25 –30 MHz frequency range, when using the rod antenna. Moreover, when the same test sample was measured between 20 and 30 MHz using a vertically polarized biconical dipole, readings between 25 and 30 MHz were often lower, sometimes by as much as 15-20 dB. Because use of the rod antenna is specified now in MIL-STD-462D to 30 MHz and the biconical is specified above 30 MHz, little if any interest appeared relative to the appropriateness of the rod antenna or it's accuracy. The undersigned however, having experienced repeated situations of equipments appearing to "fail" when tested with the rod antenna and "pass" at the same frequency using the biconical dipole, decided to pursue an investigation. What is offered here is a series of experiments and their corresponding results along with some conclusions.

Executive Summary

The rod antenna, it's grounding strap to the copper bench and the copper bench itself combine to form a resonant slot or stub distortion inside the shielded chamber resulting in a "peaking" of data measurements typically between 20 and 30 MHz when using the rod antenna. Bonding the reference plane of the antenna as well as the copper bench on a perimeter basis (i.e. front and back of the bench) reduces this effect significantly although does not eliminate it completely. Additionally, vertically polarized orientation of the biconical dipole between 20 and 30 MHz are typically lower by amounts of up to 25 dB than the corresponding rod antenna readings in the same frequency range. This effect appears to be relatively independent of the test facility although the frequency of the peak appears to be a function of the length of the copper bench top and the size of the shielded enclosure. The larger rooms and longer benches result in lower peak resonant frequencies. This effect is not apparent during the calibration of the rod antenna as that procedure simply drives the rod termination point with a flat voltage source in series with a small capacitor to simulate the rod antenna. Amongst the things that do not seem to affect this anomaly are:

a.) The length or type of coaxial cable used from the rod antenna output.
b.) The length of the rod antenna (for lengths all the way down to 6 inches)
c.) The size of the test sample.

Miscellaneous Observations

CKC Laboratories in Redmond, WA was kind enough to provide the following series of tests along with a photo of the test setup. The first graph is data taken using a rod antenna connected in the conventional manner with the grounding of the rod antenna ground plane to the bench only. These results appear as Figure 1.

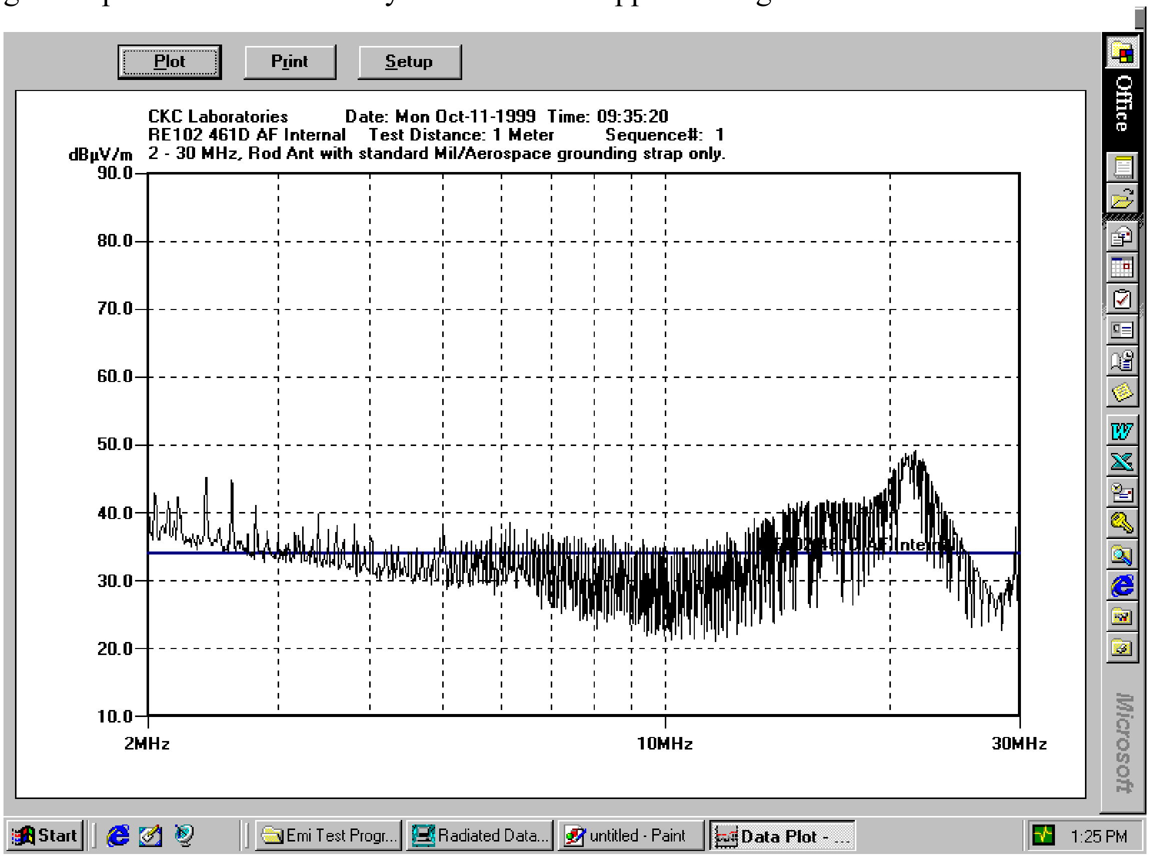


Figure 1 – Rod antenna data CKC Labs 10/11/99

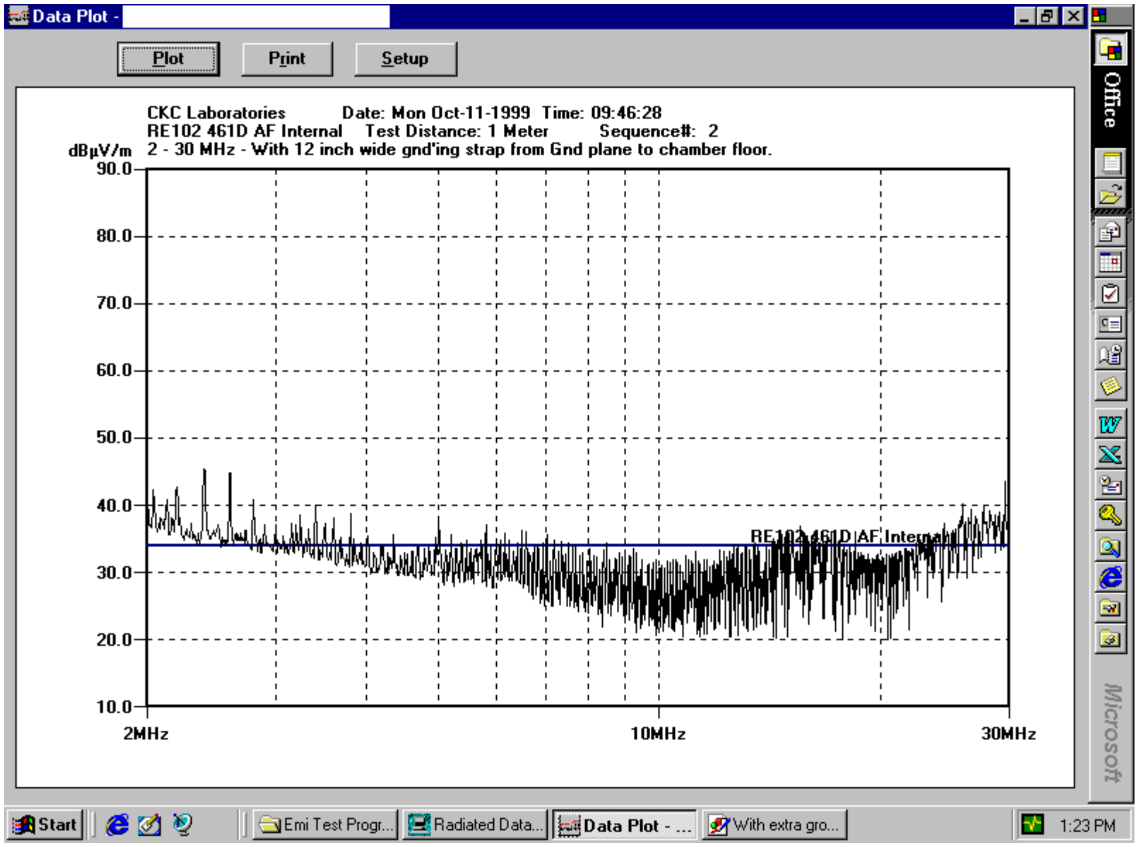


Figure 2 – Rod Antenna data with additional ground strap (same test sample)

The test setup corresponding to the data depicted in Figure 2 is shown as Figure 3 below. The Figure 1 data was taken with the identical setup with the exception that the foil-grounding strap was removed.

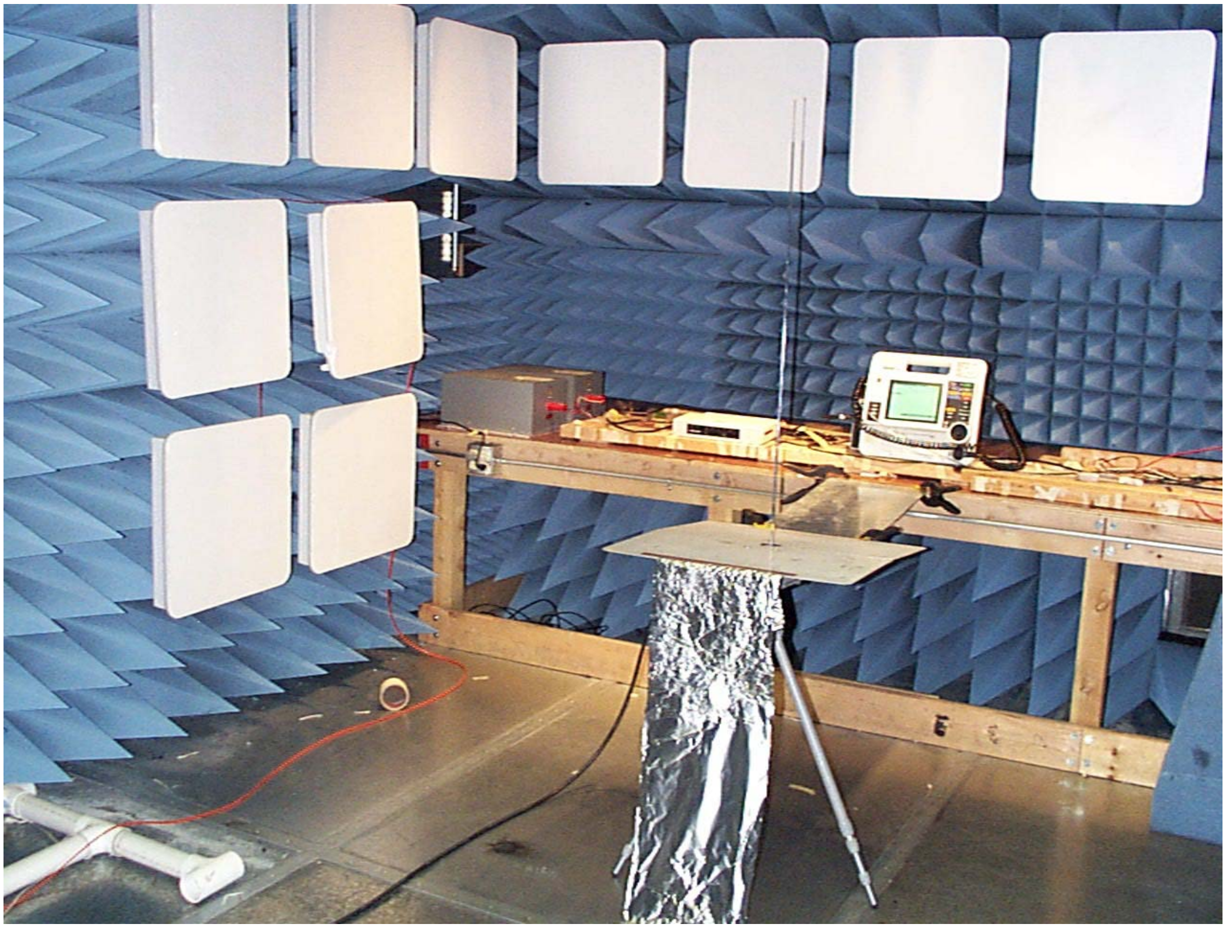


Figure 3 – CKC Rod antenna setup and experiment

The significant features of the two sets of data are the apparent "peaking" near 22 MHz in Figure 1, the shifting of the peak to near 30 MHz in Figure 2 (but not as pronounced) and an overall reduction in the readings in Figure 2 below about 28 MHz.

In April 1997, prompted by a similar situation, Garwood Laboratories Inc. performed a simple comparison of the emissions from a 1 foot long vertical wire driven by 0 dBm at 25 MHz when measured using the rod antenna and again using a biconical dipole, vertically polarized. In both measurements, the antennas were 1 meter from the emitting wire. The results appear as Figures 4 and 5 for the rod and the biconical respectively.

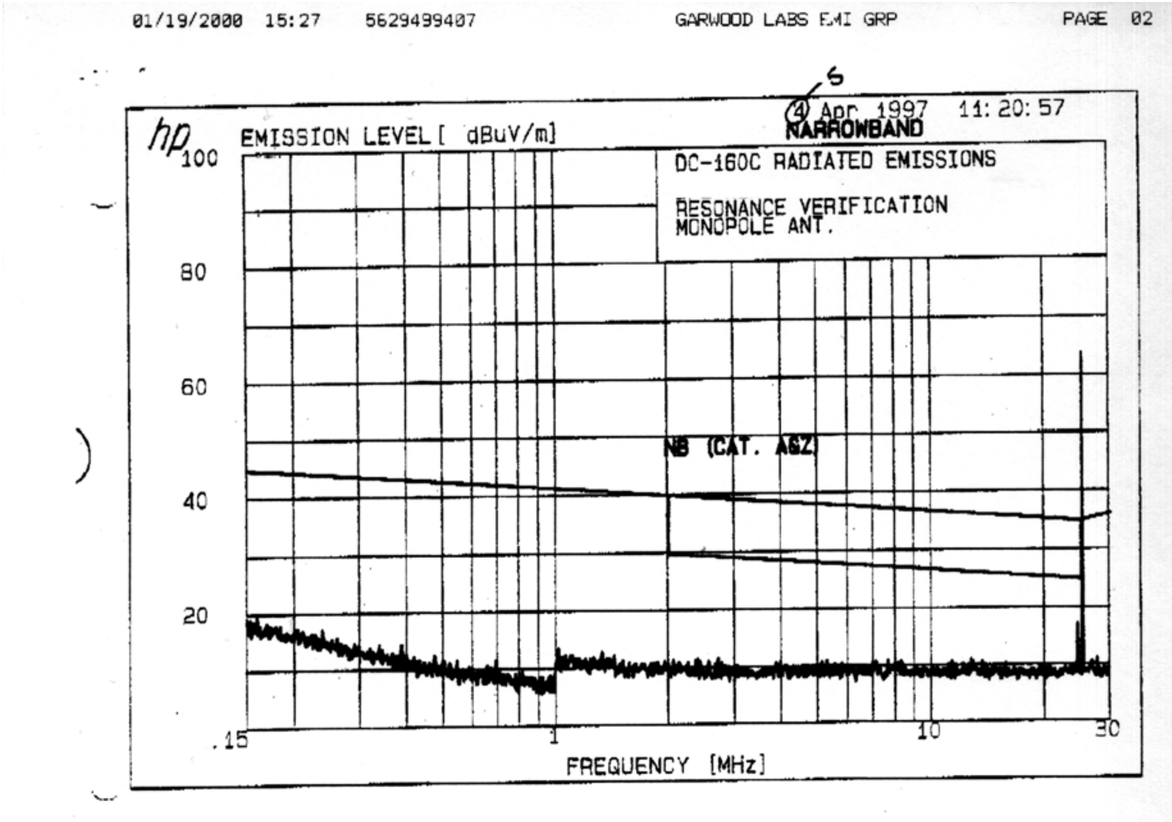


Figure 4 – Emissions from a vertical wire using Rod antenna at 25 MHz

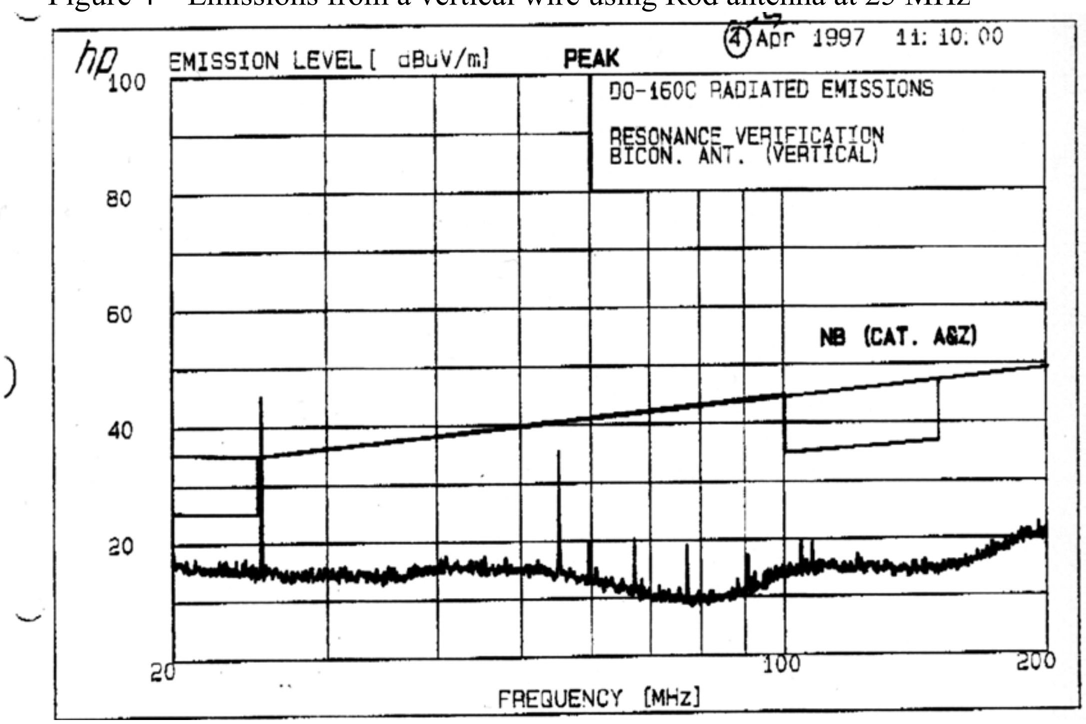


Figure 5 Emissions from same source as Figure 4 using vertical bicon.

The readings are 65 dBμV/M and 45 dBμV/M respectively at 25 MHz. This discrepancy seems significant even in the EMC business where these two calibrated antennas should seemingly provide the same answer providing they are being used appropriately.

An observation at this point however is that the internal geometry of the shielded enclosure test setup is significantly different as evidenced by the presence of what could be characterized as a "stub" emanating from the wall of the shielded enclosure via the copper bench ground plane which for all of these measurements was connected to the shielded enclosure along the rear edge of the bench only. The undersigned's suspicion at this point is that the basic rod antenna setup with the connection between the bench and the antenna reference plane constitutes and open circuited transmission line loaded by the capacitance between the reference antenna plane, the grounding strap to the bench and the screen room floor resulting in an apparent resonant circuit that tunes up in the indicated frequency range. The consequences of this resonant response is to exaggerate the field strength near the end of the antenna reference plane by an amount equal to "Q" where "Q" is the quality factor the tuned circuit just described. The measurement made with the other antenna or the rod antenna not connected to the bench, does not appear to exhibit the same degree of peaking. Figures 6 and 7 compare the emissions from a "Compower" 1 MHz comb generator using the so called "long stub" as measured with the rod antenna with no ground strap of any kind and the vertically polarized biconical dipole.

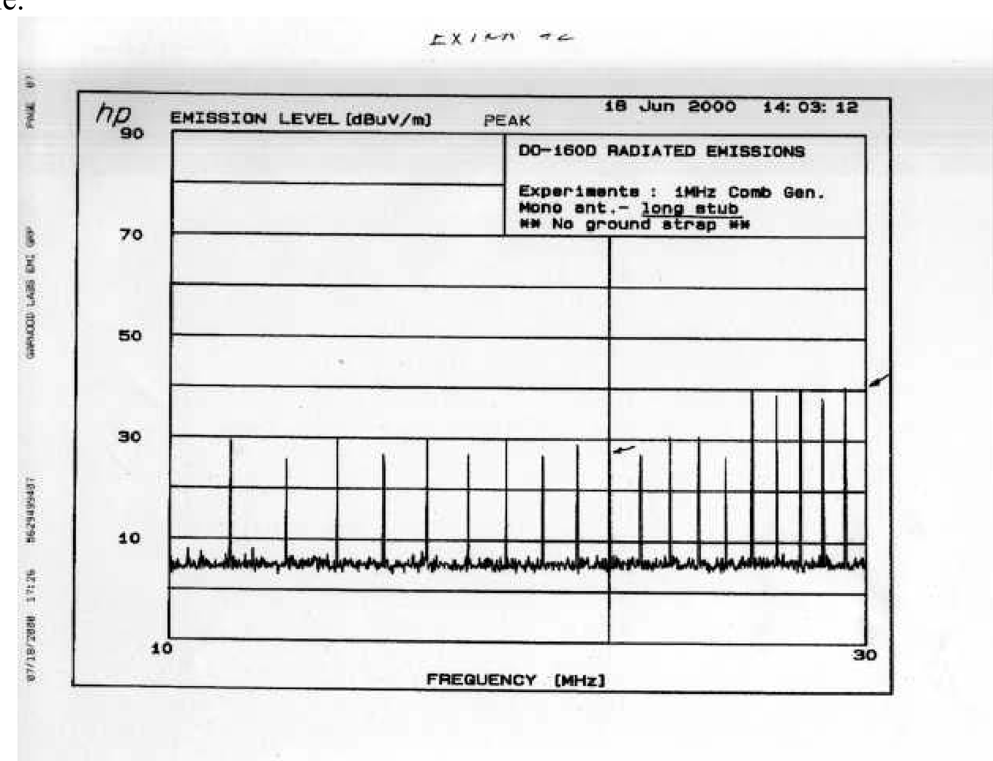


Figure 6 "Ungrounded (no connection to bench) rod antenna measurement

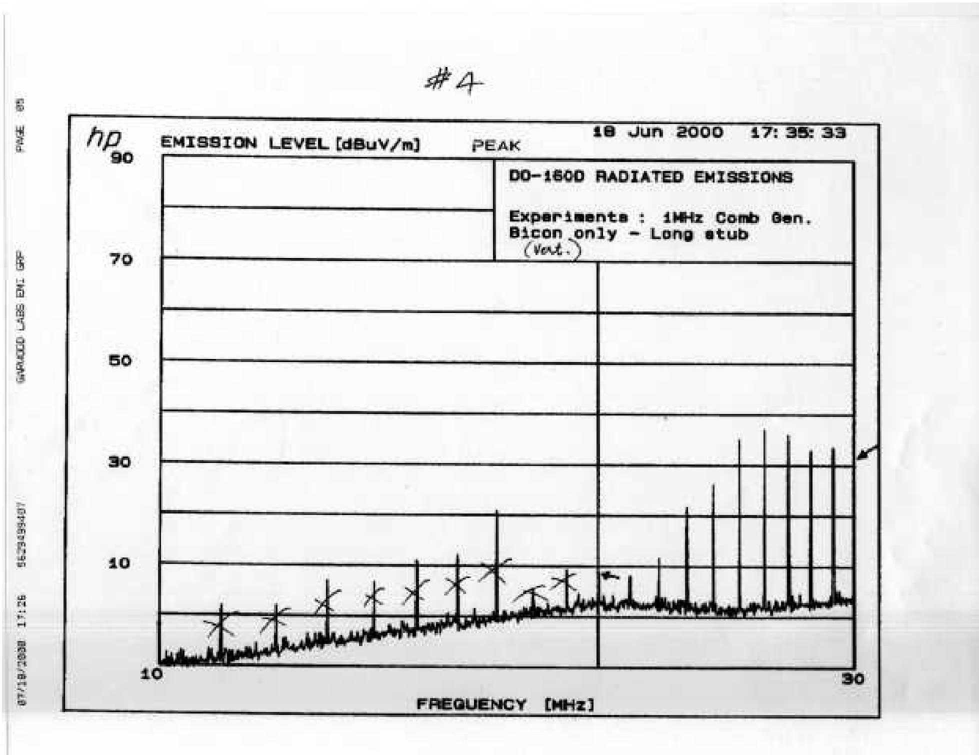


Figure 7 – Vertical Biconical Antenna Measurements *
(* Readings below 20 MHz are not valid with this antenna)

Comparing these two we see that between 25 and 30 MHz at least, the rod antenna while still presenting higher readings is within 5 dB of the biconical vertical readings. The lack of connection to the copper bench corresponding to the Figure 6 plot would eliminate the "stub" type relationship to the screen room wall present with the antenna reference plane connected to the bench. The addition of the additional ground strap done in the CKC experiment (Figures 1 and 2) also changes the resonant characteristics of the reference plane although it appears to move it up substantially probably above 30 MHz. As a final experiment performed today at Garwood Laboratories, the "Compower" comb generator was measured using 2 configurations of test antennas. Figure 8 is the result using the rod antenna grounded to the copper bench in the usual manner. Figure 9 is the result with the rod antenna plus an additional ground strap at the rear of the antenna reference plane in a manner similar to the CKC Figure 3 photo. These should both be compared to Figure 7 (biconical antenna) for further observations.

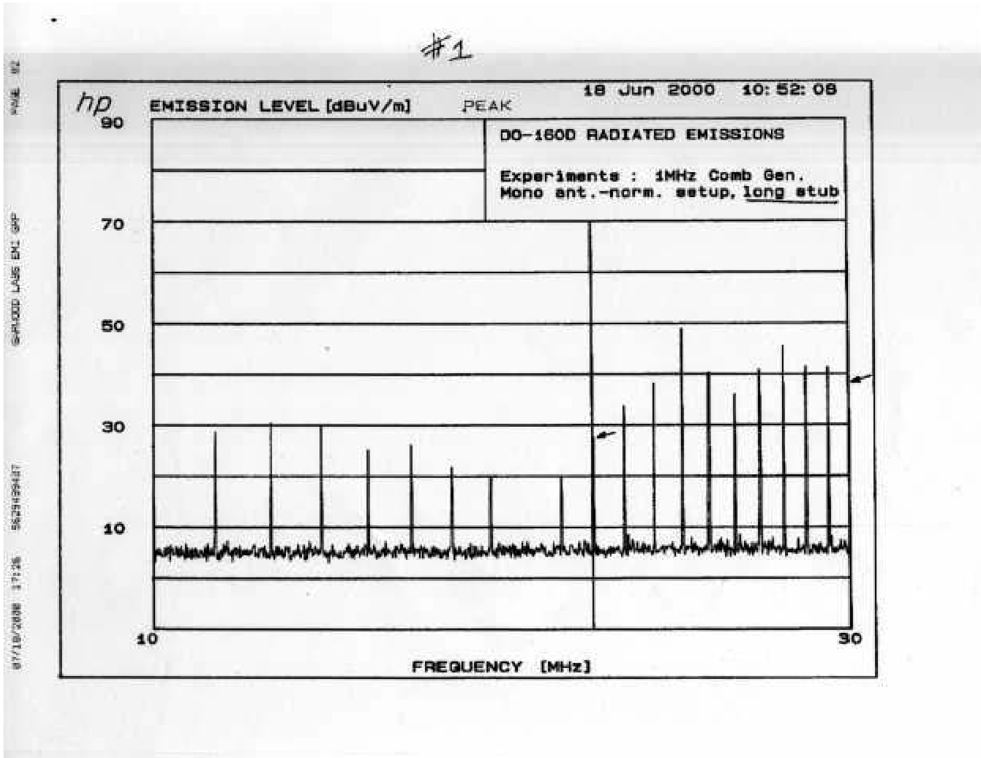


Figure 8 – Compower source, standard rod antenna setup

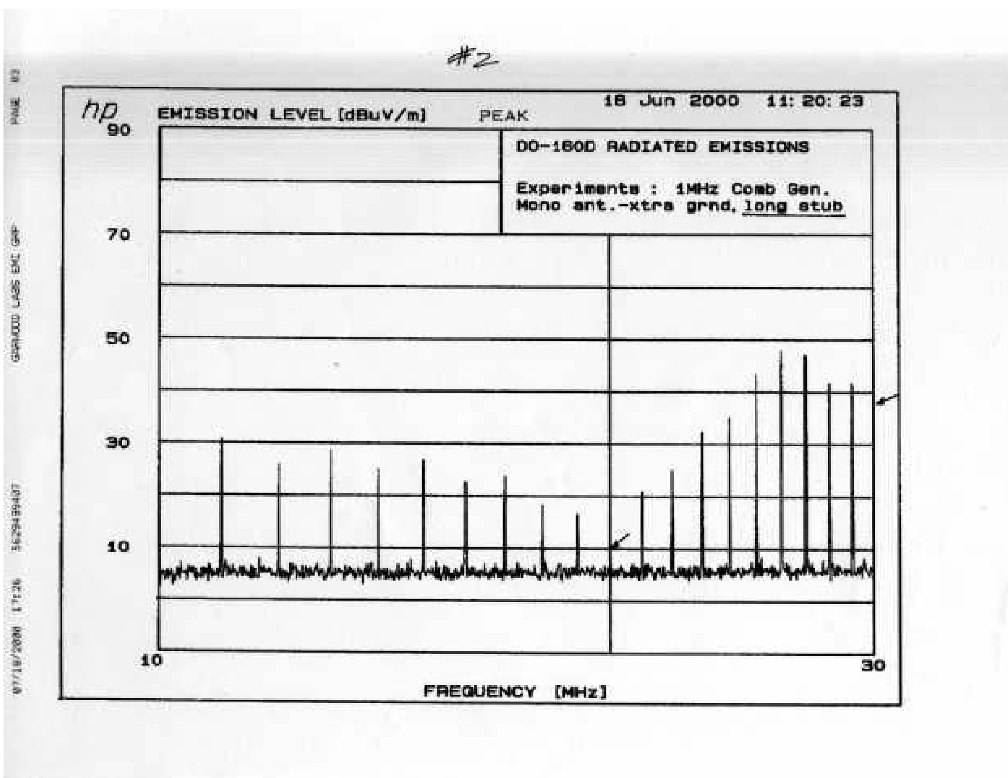


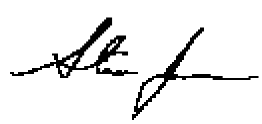
Figure 9 – Compower source Rod antenna with extra ground strap

It is important to notice the readings at 23 MHz in Figures 8 and 9. The figure 8 result is of the order of 20 dB higher than the Figure 9 result while comparisons at say 27 MHz yield answers within 3 dB of each other. It would appear that the rod setup in the Garwood room peaks near 23 MHz as compared to 21 or 22 MHz in the CKC room. Both versions of the rod antenna still exceed the Figure 7 biconical readings at many frequencies, but the additional grounding appears to eliminate the pronounced resonant effect that puts many test samples out of spec. A 20 dB penalty at a particular narrow range of frequencies seems excessive and probably counter productive to the end user in terms of serious modifications to the filtering and/or shielding schemes that may otherwise need to be implemented.

Finally, the nominal field from the “Compower” comb generator with the “long stub” is supposed to be a constant 40 dBμV/M at 1 meter distant. It would appear therefore that the most accurate result is actually the rod with no ground whatsoever, followed by the biconical above 25 MHz. None of the antennas give the correct answer most likely due to the resonant effects of the shielded enclosure. Much more rigorous treatment of this problem is obviously in order to optimize the radiated emission measurements below 30 MHz in a shielded enclosure. However, it seems reasonable to conclude at least the recommended rod antenna setup has some serious resonant characteristics attributable to the presence of the grounding strap/stub that is used for these measurements.

<u>Recommendations</u>

For greatest consistency at the 30 MHz transition from the rod antenna to the biconical data, add additional grounding to both the reference plane of the rod antenna as well as the copper bench top so that it appears grounded to the shielded enclosure both along the front edge as well as the rear. Keeping in mind that none of the conductors under discussion are intended to modify the emissions profile of the test sample, as they are all reference planes. Additional connections between these reference planes and the shielded enclosure seems appropriate and consistent with the intent of the test.



President and Principal Consultant
STEVE JENSEN CONSULTANTS INC