ATOMIC STANDARDS TEST AND EVALUATION

by

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The U.S. Army Electronics Technology and Devices Laboratory, ECOM, Fort Monmouth, New Jersey, was asked at the end of 1969 by the then Naval Applied Sciences Laboratory to conduct an extensive series of evaluations of the performance of the Hewlett-Packard Model 5061A Cesium Beam Frequency Standard under a wide range of environmental conditions. The test conditions specified by the various Systems Management Groups were based on the anticipated environment in a nuclear submarine for use in a RHO-RHO navigation system. The test program took about 6 months. The paper presented here is essentially an excerpt of an R&D Technical Report prepared by ECOM describing the approach adopted for conducting the tests and the results obtained.

Only a brief summary will be given now. For more detailed information the reader is referred to R&D Technical Report, ECOM-3371, "Performance of Cesium Beam Frequency Standards and Clock Modelling," by Erich Hafner and Edward Simon, dated December 1970.

Three ruggedized HP5061A Cesium Atomic Frequency Standards were subjected to 2 Gauss ac and dc magnetic fields in three directions, supply voltages of 94 volts, 115 volts, and 126.5 volts; temperatures of 58°F, 75°F, and 92°F; vibrations of 0.120" DA at 4 to 15 hertz and 0.04" DA at 16 to 25 hertz; and 11 milliseconds shocks of 15 g, 40 g, and 60 g. Throughout these experiments the mean frequencies of the standards, averaged for the most part over three-

day periods, remained within a 1σ limit of $\pm 1 \times 10^{-12}$, except during the ac magnetic field exposure. There, frequency deviations of up to 80×10^{-12} were observed. This ac magnetic field sensitivity was due primarily to field sensitive elements in the electronics and in the beam tube and is not an intrinsic property of Cesium Beam Frequency Standards.

The test results demonstrate that the ruggedized HP Model 5061A CS Atomic Beam Frequency Standard is capable of maintaining satisfactory operation under severe environmental conditions. No catastrophic failures were encountered at any time, and nearly all of the interruptions of normal service that did occur can be avoided if appropriate safety precautions are taken.

The Technical Report cited above provides a detailed description of the test procedures used and the results obtained, including an analysis of the various failure modes observed. Copies are available from Defense Documentation Center, Accession Nr. AD882827. A limited number of copies is still on hand at ECOM, Attn: AMSEL-TL-SF.

DISCUSSION

DR. HAFELE: It wasn't clear to me what clock you were comparing with what clock. You had two clocks and you were comparing the two clocks. What was the reference clock?

DR. HAFNER: We had three clocks. During all the tests except vibration and shock, one unit served as the reference. During the vibration and shock tests, two of the remaining units served as the reference. The comparison was made between the frequency difference between the two pairs.

MR. PITSENBERGER: What's the principle of the cesium oscillator? Secondly, are there any nuclear isotope decay processes involved?

DR. HAFNER: There are no decay processes involved. The cesium atom is stable. The cesium resonator serves as a passive device, effectively as a discriminator. It has a very high Q depending on such considerations as design and beam length. For this particular tube, the Q is in the order of 20 millions, so you have a very high Q discriminator. Its discriminating action is utilized to slave a crystal oscillator to it, to the center of the resonance.

DR. REDER: I have three questions. First, on this attitude test which caused the frequency change of two parts in 10^{12}, could that be measured fast enough to see whether there is a delay which would point towards temperature?

DR. HAFNER: I would think it would be rather difficult to detect the thermal transient there but we have observed rather large changes in the temperature. We had thermo couples distributed within the unit and outside the unit and the readings were substantially different in different attitudes. Correlation between temperature and frequency is a rather hairy problem and depends on many, many details.

DR. REDER: Second, when you made the vibrator test, did the vibrators cause any AC-magnetic fields which could possibly also have affected the cesium standards?

DR. HAFNER: This was a mechanical vibrator. We have searched for ambient AC-fields very carefully and within the resolution of our gaussmeter, which has a bandpass cutoff about 2000 Hz, we have never been able to detect any ambient AC-fields.

DR. REDER: Do you know what the source of the AC-magnetic field sensitivity is? Is it in the beam tube, in the electronics line, in transformer cores, or where?

DR. HAFNER: Dr. Cutler, would you care to answer that question?

DR. CUTLER: There are apparently several sources for the AC-magnetic field problem. There are some electronic effects and some effects in the beam tubes; generally the larger effects amount to a modulation in the electronics and then a demodulation by something vibrating inside the beam tube. Either something vibrating, or, in the case of the magnetic field, perhaps defection of ions, so we have taken steps both in the electronics to reduce the initial modulation effects and in the beam tubes to reduce the sensitivity to the magnetic field inside.

DR. REDER: On this magnetic field test is it possible that the harmonic of the AC frequency came close to the modulation frequency and caused havoc?

DR. CUTLER: That can happen, that's one of the things you have to watch out for.

DR. HAFNER: I think I can perhaps add something here. We had made the 3-day tests on the AC-magnetic field at 60 Hz. However, we have searched from 40 Hz to 400 Hz, that is, we applied AC-magnetic field over this frequency range to the coil, and when there was coincidence with the modulation frequency or harmonics, the unit would jump out of lock. This occurred at relatively small fields.

MR. CHI: In the beginning you mentioned you also tested a rubidium gas cell frequency standard. What is the result of that?

DR. HAFNER: We have not subjected rubidium gas cells to any similar tests. Not as extensively.