

INVESTIGATION INTO THE EFFECTS OF VHF AND UHF BAND RADIATION ON HEWLETT-PACKARD (HP) CESIUM BEAM FREQUENCY STANDARDS

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Abstract

This paper documents an investigation into reports which have indicated that exposure to VHF and UHF band radiation has adverse effects on the frequency stability of HP cesium beam frequency standards. Tests carried out on the basis of these reports show that sources of VHF and UHF radiation such as two-way hand held police communications devices do cause reproducible adverse effects. This investigation examines reproducible effects and explores possible causes.

I. INTRODUCTION

The need for a reliable frequency standard is common for both Department of Defense and industrial applications. The Hewlett-Packard 5061A and 5061B Cesium Beam Frequency Standards have widespread use fulfilling the need for these frequency standards.

The DoD Timing Operations Division of the U.S. Naval Observatory (USNO) undertakes the delivery and installation of cesium beam frequency standards on select Navy vessels. During some of these installations, the installed clock was observed to jump unexpectedly. On occasion, the alarm lamp would illuminate. After searching for a possible cause for these events, it was noted that these fluctuations could be correlated with instances where personnel had used hand held transceivers in the proximity of the clock. The suspicion that electromagnetic radiation may be responsible for a change in the performance of the Hewlett-Packard frequency standards led to the decision to embark upon a more thorough investigation of this phenomenon.

II. PRIMARY EFFECTS OF VHF AND UHF BAND RADIATION

The first task undertaken in the course of this research was to ascertain if radio frequency (RF) radiation had a noticeable and reproducible effect on the frequency stability of the HP cesium

beam frequency standards. Since the hand held transceivers were the suspected interfering devices, an experiment was formulated to imitate this situation.

In order to evaluate the effect on frequency stability, it was desired to see how the time interval between the clock and a known stable reference varied when RF radiation was introduced. An HP 5061B was obtained and placed in the test configuration shown in Figure 1. The 5 MHz output of this clock was compared with a 5 MHz signal derived from the USNO Master Clock (USNO MC). The time interval between these two signals was measured with an HP 5370B time interval counter (which utilized a reference frequency also derived from the USNO MC) and recorded on a desktop computer. This test setup is shown in Figure 3.

A two watt hand held UHF radio, operating on a frequency of 462.575 MHZ, was obtained. This radio is of the type often used for job site communication. After obtaining the natural rate of the clock, the UHF radio was placed five feet from the front of the clock and keyed. The time interval between the clock under examination and the USNO MC was recorded several times per second by the data acquisition system (DAS). The collected time interval data clearly showed that the rate of the clock accelerated dramatically from the normal rate when the UHF radiation was applied, and returned to its normal rate after the radiation ceased. This response of the 5061B is shown in Figure 2. The time offset that had been acquired while the RF was present remained. Repeated tests of varying lengths were conducted and produced similar results.

In order to ensure that the data collected was indicative of the effect of the RF on the clock, not on the counter, the effect of the RF energy on the counter's measurements had to be recorded. The start and stop inputs to the counter were fed with different lengths of cable connected to the USNO derived 5 MHz source. The different lengths of cable provided a stable, fixed time interval (TI) to measure. The TI data output of the counter was recorded for five minutes to record any natural fluctuations. Then the UHF radio was placed in contact with the counter and keyed as the computer continued to record the time interval measurements. After ten minutes, the radio was turned off and the counter was observed for five more minutes. Fluctuations in the TI data were seen while the RF was present, but they were well below the levels of fluctuation seen when recording the time interval between the clock and the reference frequency. The counter did not acquire a permanent offset from the Master Clock as the HP frequency standard had. In order to minimize the effect of the RF on the accuracy of the counter's measurements, precautions were taken to keep the counter on a grounded surface at least ten feet away from the radiation source and shielded from direct RF exposure by the metal cases of other equipment. Care was also taken to keep the coaxial connections short and away from the source of radiation.

The above experiment was repeated with the VHF radios used by the USNO Police, operating on a frequency of 140.3MHz, and similar results were observed. Unfortunately, it was only possible to borrow these radios for a short length of time.

III. FREQUENCY AND POWER DEPENDENCE

Having established that the HP 5061B cesium standard was sensitive to RF radiation, it was of interest to explore the dependence of this effect on the frequency and power of the RF energy. A Fluke 6080 RF signal generator was used as the source of RF energy. The output of the signal generator was fed to a straight wire antenna one foot five inches in length, placed two feet in front of the clock under examination. The DAS program was modified to perform the following procedure. First, the clock was monitored for a length of time with the RF output silenced. Then, the program activated the signal generator and set the frequency to the first frequency of interest. After monitoring the clock for a specified period of time, the program changed the frequency of the signal generator to the next frequency of interest. When all the selected frequencies had been monitored, the signal generator output was silenced and the clock was monitored for a specified period of time. The power of the signal was left constant throughout the sweep. All program parameters were entered by the user, making this a very flexible DAS. This experiment setup is shown in Figure 4.

In order to know the real RF strength that was incident upon the clock for any frequency, the frequency response of the antenna needed to be calculated. A matched straight antenna was fabricated and was placed two feet away, parallel to the transmitting antenna. The receiving antenna was connected to an HP 8562 spectrum analyzer. The magnitude of the signal at this antenna was recorded as the signal generator was swept across the frequency band of interest. The matched nature of these antennas allows correction to be made for the characteristics of the antenna. The frequency response plot is shown in Figure 5.

It was found that the clock exhibited sharply accelerated rates around two particular frequencies (Figure 1). The first was at 128 MHz, and the second was around 150MHz.

IV. INVESTIGATION OF POSSIBLE CAUSES

The investigation now turned to isolating areas within the clock that are sensitive to RF radiation. The general strategy was to observe the signals at various points within the clock both under normal conditions and while the clock was exposed to RF radiation. The nature of some of these signals made observation on an analog oscilloscope difficult, necessitating the use of a digital oscilloscope (HP 54504). In order to isolate stages of the control feedback loop, the links between subassemblies were removed as required. The test points of interest could then be observed both before and during radiation. Particular care was taken to discriminate between those effects that were caused by the RF radiation and those that were caused by the modification of the feedback circuits. Such discrimination was made easy by the fact that the RF source could be turned on and off at will.

The following sections describe the effects noted at several points within the clock and the causes that they tend to imply.

A DC Control Voltage and Synthesized Frequency.

The DC control voltage took on a very large negative value when the UHF radio was placed near the clock. When the UHF radio was at a distance of two feet, the control

voltage was measured at approximately -300mV. The output from the external Synth jack did not appear to be affected even when the radio was in very close proximity to the clock. The Fluke signal generator was used to trigger the scope in order to determine if there was a phase shift in the synthesizer test point signal when the RF was applied. No such phase shift was observed, even after the clock's alarm light was illuminated.

B A7 AC Amplifier Assembly and A8 Phase Detector Assembly.

The AC error signal at test point J6 on the A7 AC amplifier module was seen to produce a large sinusoidal wave form of greater than 1.9 V peak-to-peak when the handheld radio was keyed nearby. The 274 Hz monitor point J2 normally showed a sinusoidal wave form which became mixed with an irregular sawtooth wave form with many transients when the radio was keyed.

The error signal available at test point J1 on the A8 phase detector assembly jumped to a peak voltage of nearly 3 V when the RF was applied. When the link between point J4 on the A7 assembly and J3 on the A8 assembly was removed, the A8 module showed much less response to RF, even when the handheld radio was placed nearly in direct contact.

An A7 assembly identical to that in the clock was obtained. The output from this unit, which was powered by two DC power supplies, was observed. The unit showed a very strong response to RF energy. When RF was applied, a sinusoidal signal of approximately 137 Hz was obtained at test point J6. The unit drew a large amount of current when RF was applied. The current peaked when a +20 dBm signal from the straight wire antenna was placed one inch away, reaching nearly 3 amps. Even at a distance of three feet, a current of 0.5 amps was still drawn from the power supplies.

C Cesium Beam Tube.

Proceeding one more step backwards in the control loop, the signal output of the cesium beam tube was examined. When radio frequency radiation from the signal generator was applied to the clock, a sinusoidal component with the same frequency as the RF source was seen at the output. This output signal was very noisy as viewed on the oscilloscope. With the oscilloscope set to repetitive mode, a wave form that was much more clearly defined was built up. At 200 MHz, the output RF voltage was about 63 mV peak-to-peak. At 150 MHz, the maximum voltage was seen at 150 mV peak-to-peak. There was no apparent change in the RF voltage when the A1 assembly was removed from the feedback loop. There was also no apparent change in RF voltage when the link between the A3 Frequency Multiplier and the A4 Harmonic Generator was removed.

From these observations, it seems reasonable to conclude that the RF radiation is being introduced to the feedback loop through the cesium tube assembly. It is quite possible that the high-voltage power supplies provide the means by which incoming RF radiation is transported into the cesium beam tube. While there is capacitative coupling to ground, it is in parallel with an inductance formed by the transformer. The combined reactance of these elements may form an oscillator at certain radio frequencies. At the frequencies of resonance, these capacitors would offer no protection against the transport of RF energy.

V. POSSIBLE MODIFICATIONS TO EXISTING 5061 CLOCKS

To prevent radio frequency pickup in the cesium beam tube, it might be possible to place an RF choke coil in series with the DC outputs of the high-voltage supply modules. This will substantially increase the resistance seen by RF signals, and may decrease the RF component introduced into the tube. A high-voltage low-value capacitor placed after the choke coil would act to short any RF signal to ground while leaving the DC current unaffected. This modification would not affect the DC rectification circuit.

A more extensive modification would be to replace the transformer with a semiconductor-based voltage multiplication circuit, eliminating the inductive effect of the transformer coils. This may be a superior solution from an RF rejection standpoint.

It is probably not a practical option to filter the RF from the output of the cesium beam tube. In order to reject RF after the tube, an RF shunt capacitor could be run to ground. Unfortunately, this could affect the operation of the clock by introducing a phase shift in the signal. A more reasonable approach might be to use parallel narrow-band bandpass filters to allow only the desired signals to pass. The most reasonable way to protect the A7 AC against RF pickup and amplification may be through the addition of extra shielding.

Clock Rate vs. Frequency and Power

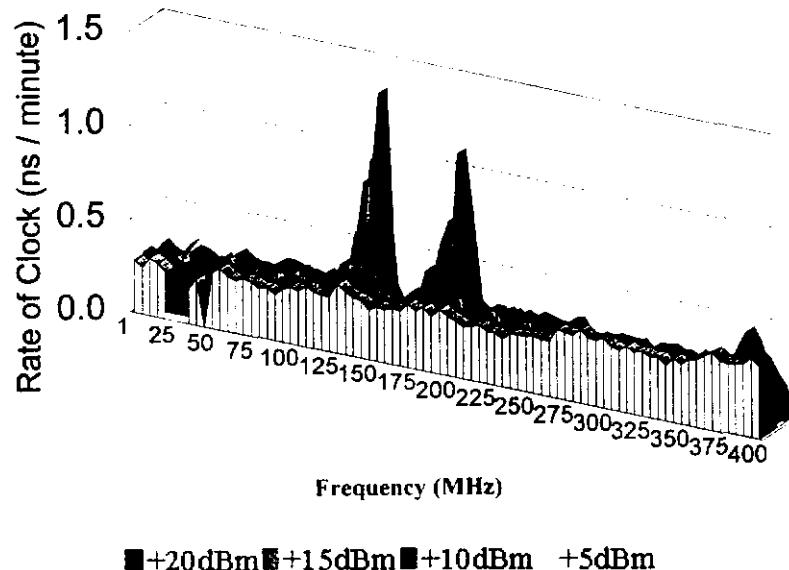


Figure 1 : Clock Rate vs. Frequency and Power

5061B Offset

2 Watt UHF Radio Five Feet Away

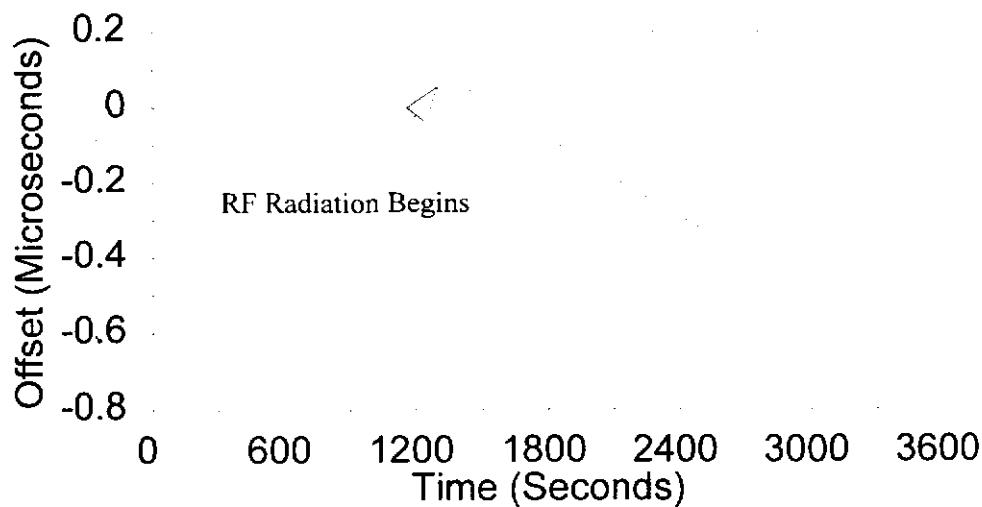


Figure 2 : UHF Response

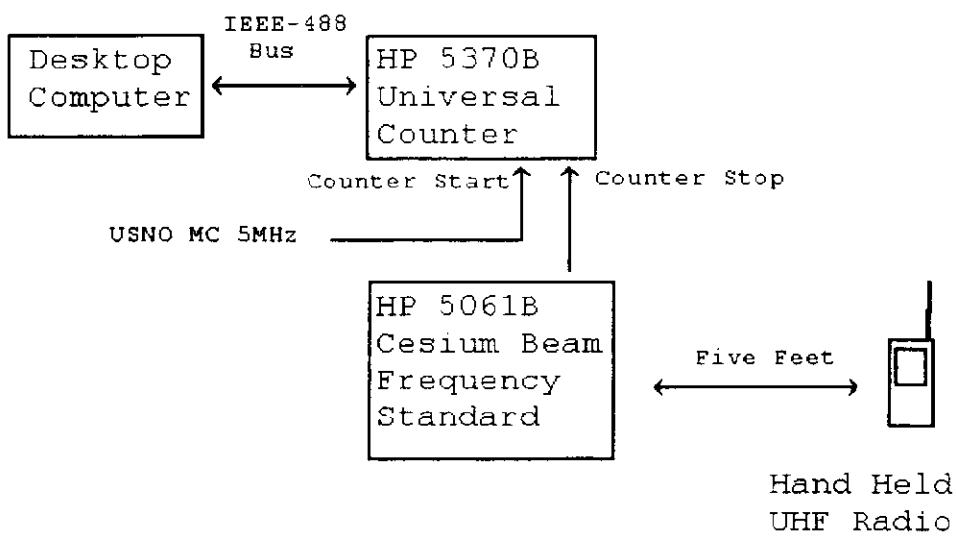


Figure 3 : UHF Experiment Setup

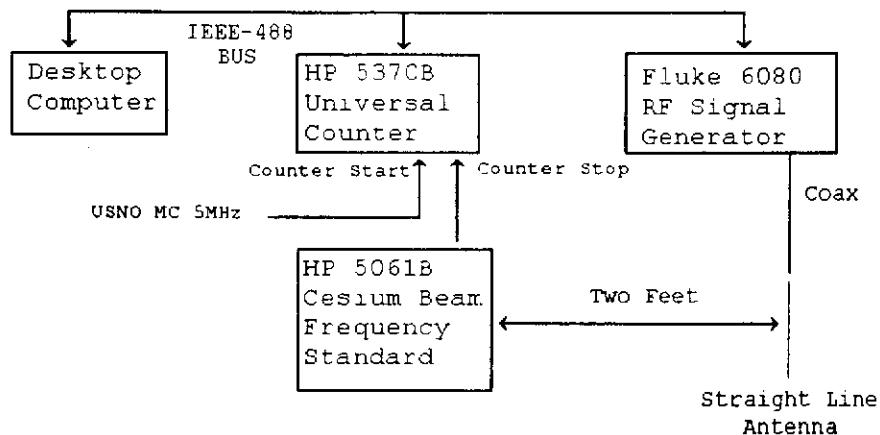


Figure 4 : VHF Experiment Setup

Antenna Frequency Response

+20dBm Two Feet Separation

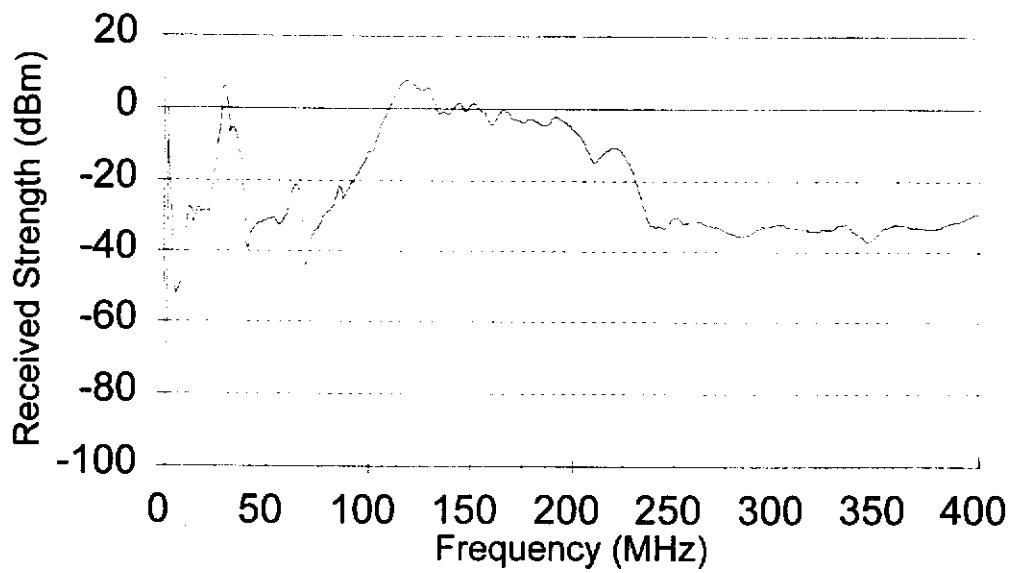


Figure 5 : Antenna Frequency Response