ENVIRONMENTAL EFFECTS ON ERRORS IN TWO-WAY TIME TRANSFER

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Abstract

We have investigated errors in two-way time transfer due to environmental fluctuations in temperature and power levels. The overall temperature coefficient of two earth stations at the National Institute of Standards and Technology (NIST) have been found to be on the order of 100 pS/K. Sub-component temperature coefficients are as high as 400 pS/K. The errors in two-way time transfer due to variations in power levels have been measured to be as large as 12 nS. These errors are due to distortion in the pn sequence due to gain compression in the earth-station.

Introduction

The time and frequency community relies on two-way satellite time and frequency transfer (TWSTFT) for synchronization and clock comparisons out of the laboratory setting.

Errors in TWSTFT arise due to non-reciprocity in path delays, Sagnac effect and station delay differences. Errors due to non-reciprocity in path delays and the Sagnac effect can be corrected to better than 100 pS [1]. The earth-station delays remain as a large source of error in TWSTFT. Environmental effects such as temperature, power level fluctuations and humidity can cause changes in these station delays compromising the stability of TWSTFT. The effects of temperature and power level fluctuations are reported.

Measurements

A 3.7m earth station and a VSAT type earth station were used in these experiments along with a transponder located on a mountain about 10 km. away. The modems are Mitrex modems. Two eight-channel data acquisition units were used to record temperature data in real time. The two-way time transfer sessions were conducted using a common clock [2] over periods of four to six hours during the early afternoon when the outside temperature remained fairly constant (+/- 3 degrees C). For a stationary transponder the time at station A is the sum of the transmit (TX) delay of station B and the receive (RX) delay of station B.

The temperature dependence of the RX and TX delays can be obtained by raising the temperature of one earth-station while the temperature of the other one remains constant. The temperature sensitivity of different earth-station sub-components such as up-converters, amplifiers and down-converters were measured by selectively altering the temperature of these devices one at a time.

The effect of gain compression on the errors in two-way time transfer were measured by driving the up-converter of the 3.7m earth-station into compression. The 70 MHz output of the Mitrex modem was amplified by 20 dB and a step attenuator was used to vary the power going into the up-converter. The experiment was carried out during stable environmental conditions and all data were obtained in thirty-five minutes.

Results

The measurements of temperature data on the earth-station showed temperature variations of thirty degrees C over a six hour period from early morning to afternoon. The TX plus RX delays for an earth-station had a temperature coefficient of about 200 pS. In order to understand which parts of the earth-station were most sensitive to temperature variations we placed temperature sensors on various sub-components such as up and down-converters, synthesizers and filters. Some of this data for the VSAT earth station is displayed in figures 1 and 2. Figure 1 shows the TX plus RX delays for the VSAT earth station as a function of time (in seconds) since the beginning of the experiment. The second figure shows the temperature data logged during the two-way session as a function of time. From this data it is possible to estimate the temperature coefficients of the various sub-components. Some of these sub-components have temperature coefficients as large as 400 pS/K.

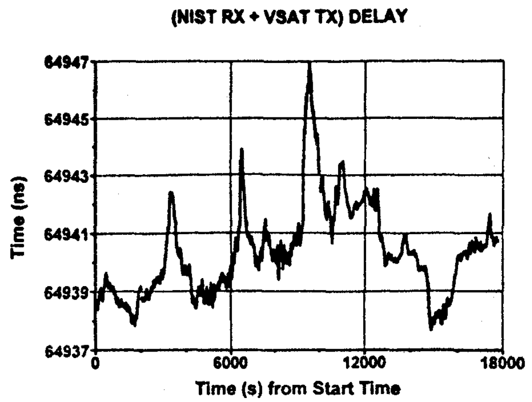

Figure 1.

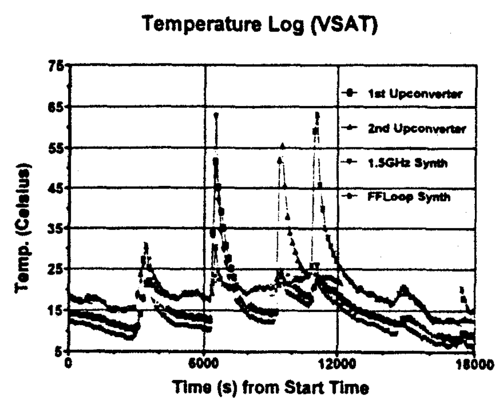

Figure 2.

Distortion of the pn sequence due to gain compression can also give rise to large errors. The dependence of the apparent earth station delay on the input power level of the 70 MHz signal is shown in figure 3.

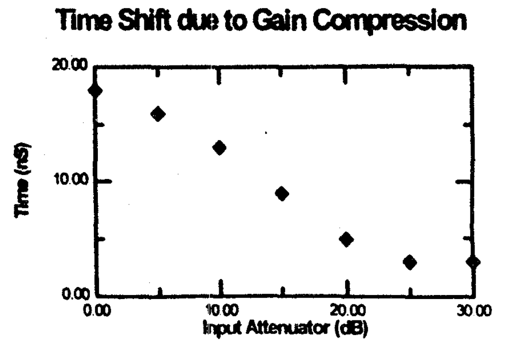

Figure 3.

Conclusions

These results suggest that the errors in two-way satellite time transfer are greatly affected by the environmental sensitivities of the earth stations. By eliminating the environmental sensitivities of the earth-stations it will be possible to conduct two-way time transfer to unprecedented stability. With the real-time monitoring of environmental conditions as well as real-time measurement of RX and TX delays using a satellite simulator [3] the earth station delays should be able to be corrected to a level much less than 1 nS.

References

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