PRECISE FREQUENCY CALIBRATION USING TELEVISION VIDEO CARRIERS

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Abstract

The availability of inexpensive and quick precise frequency calibration methods is limited. VLF and GPS do offer precise calibration. However, antenna placement, cost of equipment, and calibration time place many restrictions on the user.

The USNO maintained line-10 television Time of Coincidence (TOC) of station WTTG, channel 5, Washington, DC requires a frequency stable video carrier. This video carrier, 77.24 MHz, is controlled by the same cesium beam standard controlling the TOC of line-10.

Excellent frequency comparisons against this video carrier have been accomplished at 95 miles (153 km). With stable propagation and a three foot wire antenna, a part in 10^9 can be determined in a few minutes.

Inexpensive field equipment with a synthesized 1 kHz offset from the video carrier offers parts in 10^{11} calibrations in a few minutes using an oscilloscope as a phase comparator.

INTRODUCTION

The accuracy of precise time and time interval (frequency) has increased at a phenomenal rate over the years. Atomic standards and modern means of communications now provide us values not dreamed of a few decades ago. The scientific and military worlds are tied together to within a few nanoseconds. While those of us involved in the PTTI arena apply precise accuracies to our everyday work, a large segment of the general population that needs PTTI has been left behind. This lag has left thousands of daily users where they were thirty years ago at a part in 10^7 using WWV on shortwave. Low frequency phase tracking, Loran-C, GPS/GLONASS and the like are not easily accessible tools for many in the general communications fields.

METHODS AND LIMITS

The following means of dissemination, while able to provide PTTI results, have limiting factors to the general user. The following factors are typical for general communications personnel:

VLF (3-30 kHz), 10^{-11} or better, requires expensive receivers and special antennas. Calibration time is in hours, full knowledge of diurnal phase changes is necessary.

LF (30-300 kHz), 10^{-11} to 10^{-13}, requires expensive receivers and timing equipment. European users can use stabilized broadcast carriers (90-200 kHz).

MF (300 kHz-3 MHz), limited to 10^{-7} unless daytime groundwave signals are available, low cost receivers. While phase stable standard broadcast stations (0.54-1.6 MHz) could be used, none are currently in operation (North America).

HF (3-30 MHz), limited to 10^{-7} unless groundwave signals are available, low cost receivers.

VHF (30-300 MHz), 10^{-12} (see below), low cost receivers.

UHF (300 MHz-3 GHz), 10^{-12}, low to high cost receivers, generally line of sight range and subject to phase jitter proportional to frequency increase. Satellite signals subject to orbital changes, GPS is too expensive.

SHF (3-30 GHz), 10^{-12}, medium to high cost receivers, generally limited to line of sight and subject to phase jitter proportional to frequency increase. Satellite signals subject to orbital changes.

LINE-10 (TELEVISION), 10^{-11}, medium to high cost receivers, currently available only on WTTG, channel 5, Washington, DC. Requires clock comparison of specific line 10 television pulse that occurs every 1,001 seconds. Meaningful calibrations require an hour or longer under stable propagation conditions.

COLOR SUBCARRIER, 10^{-11}, medium cost receivers, now generally unreliable due to network routing changes, satellite orbital changes, and the mode of station operation.

NIST AUTOMATED COMPUTER TIME SERVICE, 10^{-6} to 10^{-8}, low cost, but requires computer, modem, and several long distance telephone calls. Time period for calibration is 20 minutes to 24 hours depending on needs.

USAGE DEMANDS

While timing demands to a millisecond can be met by many of the above discussed methods, by far the greatest need of the general communications worker is frequency calibration. The workhorses of the communications industry are the digital counter and digital synthesizer (service monitor). Affordable test equipment capable of parts in 10^8 or better are generally found in use. The demand of setting operating frequency to a few parts in 10^9 has become commonplace in industry. Unfortunately, field verification of test equipment time bases can not be accomplished in an easy and affordable manner. These general users are in need of a low cost, propagation stable, and quick and easy to use precise frequency source.

PRECISE TELEVISION VIDEO CARRIERS

At the present time USNO operates a phase stable video carrier on station WTTG, channel 5, Washington, DC. This station's 100 kW transmitter can be used up to 150 miles (240 km) with a short wire antenna as a reliable precise frequency source at its operating frequency of 77.24 MHz. With the addition of other select television stations throughout the United States operating precise controlled video carriers, large percentages of the general population can be supplied with the needed precise frequency calibration source. Precise operation by a single station in each of the top 10 television markets of:

New York City, Los Angeles, Chicago, Philadelphia, San Francisco, Boston, Detroit, Dallas-Ft. Worth, Washington, DC, and Houston will provide service to better than one-third the country's population. The addition of markets 11-20: Cleveland, Atlanta, Minneapolis-St. Paul, Miami, Seattle-Tacoma, Pittsburgh, Tampa-St. Petersburg, St. Louis, Denver, and Phoenix will include better than 45 percent of the general population.

CONSIDERATIONS AND OBSERVATIONS

The selection of the lower numbered television channels (2-6) operating 55.25 through 83.26 MHz is preferred due to their longer signal range and better propagation phase stability, just to name a few factors. Identification that the system is operating precisely can be accomplished by a carrier phase change lasting a few seconds occurring every five minutes. Such an identification phase change would not affect the received picture if this phase change transition is on the order of 50 ms. Such identification phase changes may be accomplished with reactance phase changes in the transmitter far isolated from the primary frequency source. Video carriers controlled by in-house cesium or rubidium standards can be directly compared by normal methods such as VLF and GPS.

The WTTG phase stable carrier has been observed for a number of years at a location 95 miles away. A high stability quartz frequency standard is continuously phase compared against WWVB operating at 60 kHz. This quartz oscillator drives a synthesizer with an output 1 kHz removed from the WTTG video carrier (77.239 vs. 77.24 MHz). A communications receiver supplies the detected 1 kHz beat note to a dual trace oscilloscope. The second oscilloscope input also has a 1 kHz input derived from a divided output of the quartz oscillator. Frequency differences between the WTTG carrier and the local quartz oscillator are noted as drift displays on the dual trace oscilloscope. At WTTG's frequency of 77.24 MHz a 1×10^{-9} difference results in a cycle beat once per 12.94 seconds. Careful expanded-scale oscilloscope observations provide parts in 10^{11} in 10 minutes. Short-term propagation phase changes are easily recognized and can be ignored. The video carrier can also be compared using the zero beat method, but accuracy errors become a factor during signal level fades and propagation phase changes.

Low cost VHF receivers and easily constructed video carrier offset phase lock loop generators operating from the user's time bases can make this precise frequency calibration method ideal for those within range of any television station operating with a precise video carrier.