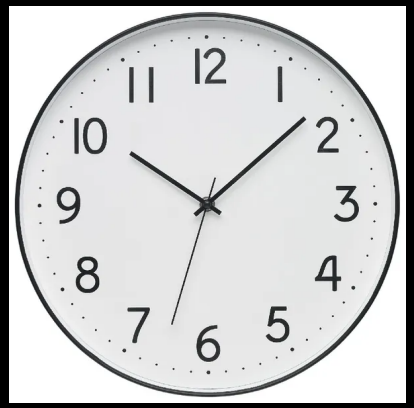
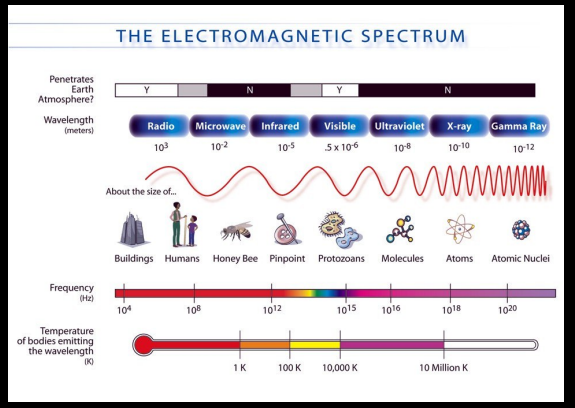
Time and Frequency Standards

Why they are Important to Amateur Radio

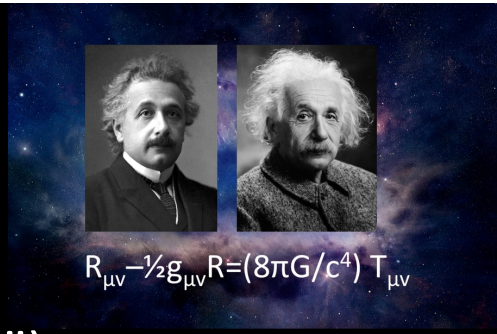




Two different, but related products

- ***Frequency Standard:*** Provides an accurate reference frequency – important for dial frequency accuracy, staying in the correct spectrum, keeping clocks on time.
- ***Time Standard:*** Tells us exactly what time it is – important for things like operating FT8, knowing when to start a net, predicting/tracking satellite passes – or how much time has elapsed like the transmit timer in radios.
- NOTE: Frequency standards do not know what time it is. However, time standards require very accurate frequencies. Confusingly, both are often called *"timing" or "clock".*

Two different, but related products



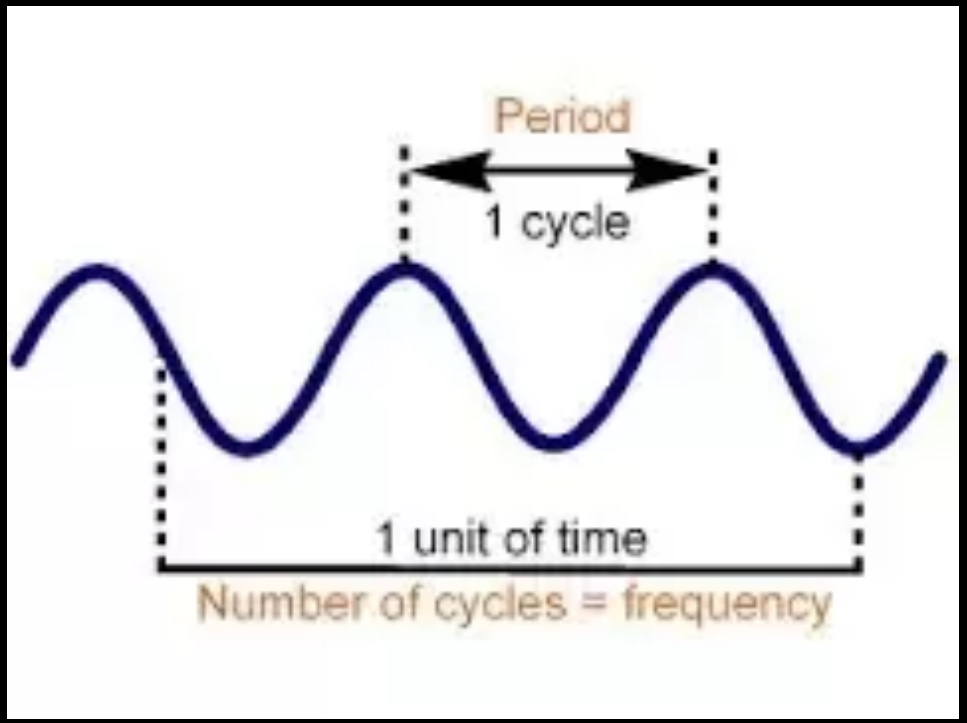
- ***Period*** ("T" for time duration) is the inverse of ***Frequency*** ("f").

  T=1/f

  If 1 MHz = 1,000,000 cycles per second, then 1/1 MHz means the period or time duration of each cycle is 0.000,001 seconds.

  Conversely, if we count the occurrence of each cycle of a 1 MHz signal, when we get to 1 million, one second will have elapsed.

Two different, but related products



Look familiar?

- You may have seen something similar before when you calculated wavelength.
- Wavelength is the distance a signal with travel over one period or cycle.
- To figure wavelength we just multiply the period (T) by the speed of light.

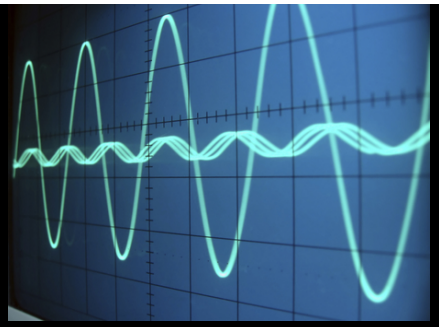
  1/146.520 MHz = T of 0.000,000,006,825 seconds

  T*300,000,000 m/s = 2.05 meters | T*984,000,000 fps = 6.72 feet

Or take the shortcut by dividing the speed of light by the frequency.

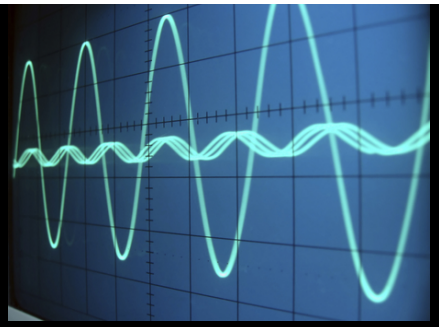
300/146.520 MHz = 2.05 meters | 984/146.520 MHz = 6.72 feet

Frequency Standards



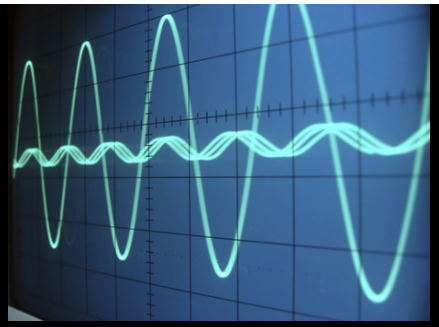
- AKA *Oscillators*.
- Can generate any periodically repeating signal including sine waves, square waves, saw tooth waves, etc.
- Sorted by accuracy & stability into Stratum Levels.
- Can range from mechanical devices (mechanical watches/clocks) to L-C tank circuits or 555 IC chips to crystal oscillators (XO - found in quartz watches) and TCXO and OCXO to Rubidium and Cesium beams, to Hydrogen MASERs and Atomic Fountains.

Stratum Levels



- Refers to how good the oscillator is and if it is stand alone, primary, or disciplined from another oscillator. Major levels are:
- ***Stratum 1:*** Accuracy $1x10^{-11}$, time slip if driving a clock <864 nanoseconds per day (that is about 1 second every 3,170 years).
- ***Stratum 2:*** Accuracy $1.6x10^{-8}$, time slip <8.64 microseconds per day.
- ***Stratum 3:*** Accuracy $4.6x10^{-6}$, time slip <32 milliseconds per day (about 1 second every 31.25 days)

Frequency Standards



- Crystal Oscillators (XO) are inexpensive and widely used and adequately stable for many things, but drift with temperature.
- Temperature Compensated (TCXO) and Oven Controlled (OCXO) Crystal Oscillators are increasingly stable, but increasingly expensive.
- Rubidium oscillators get into the realm of “atomic” standards and are super stable, generally Stratum 2, but up to 1 – can cost a few thousand dollars.
- Cesium beams use radioactive Cesium and are super stable, up to Stratum 1, but can cost over $20,000.
- Hydrogen MASERs and Atomic Fountains – quite large and very expensive, can cost more than a house.

OK, so this affects me how?

- The heart of every radio, TV, computer, or clock are oscillators. For radios they keep us on frequency and keep our signals clean and understandable. If you have ever done any Single Side-Band (SSB) voice and some of the other people sound weird, like they were breathing Helium, it is often because someone is off frequency just a little, likely due to an internal oscillator being just a little off frequency.
- Lower quality oscillators are why some clocks or watches don't keep good time and why computer clocks may drift significantly when removed from a network for a few days.
- Also critical for navigation, banking, power grid, telecommunications.

OK, so this affects me how?

- Unfortunately, unless your radio has an input for an external frequency reference, the internal oscillator must be manually adjusted to be as close as possible to a known reference signal.
- More common for people to perform a frequency test to WWV or a W1AW frequency test and then learn how far off their radio is. They can then compensate by changing the dial frequency.

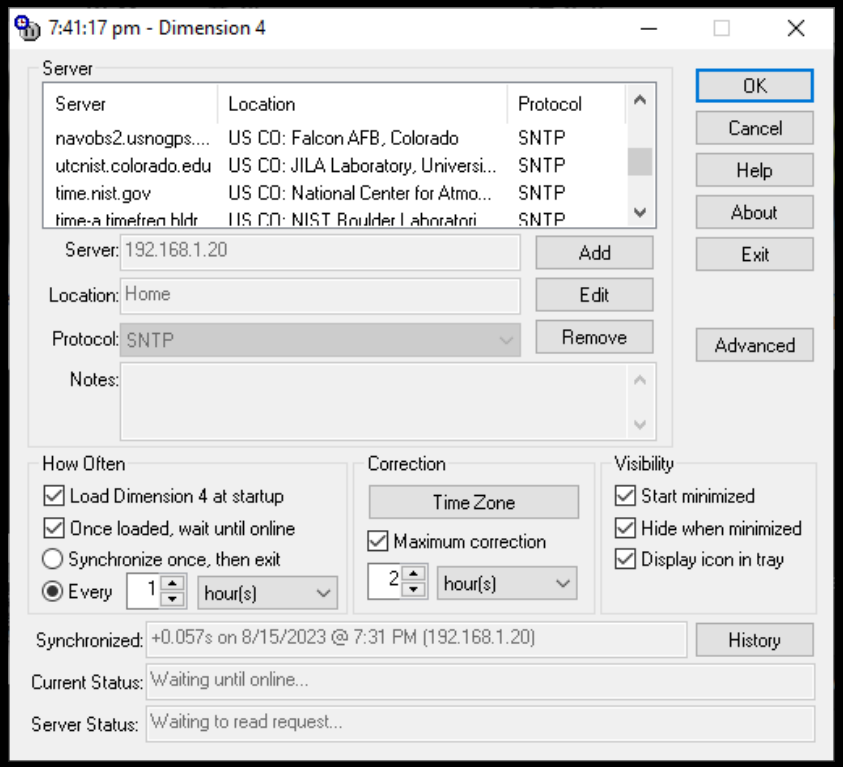
Time Standards

- Used to set clocks and in some cases to discipline or adjust oscillators.
- ***WWV*** is broadcast on 2.5, 5, 10, 15, and 20 MHz.
- ***WWVB*** used by radio controlled “atomic” clocks is broadcast on 60 kHz.
- ***USNO*** telephone: (202) 762-1401, (202) 762-1069, (719) 567-6742.
- Computers reference *NTP* (Network Time Protocol) servers. You can choose which NTP server to use (except on Android devices). NTP servers have very accurate internal oscillators and sync back to a master reference (GPS, NIST, or USNO).
- GPS receivers get extremely accurate time from the military GPS satellites, which in turn reference the USNO. Most NTP servers get their time from GPS. Often used to discipline oscillators. BTW a time accuracy of 10 nanoseconds equates to 10 ft.

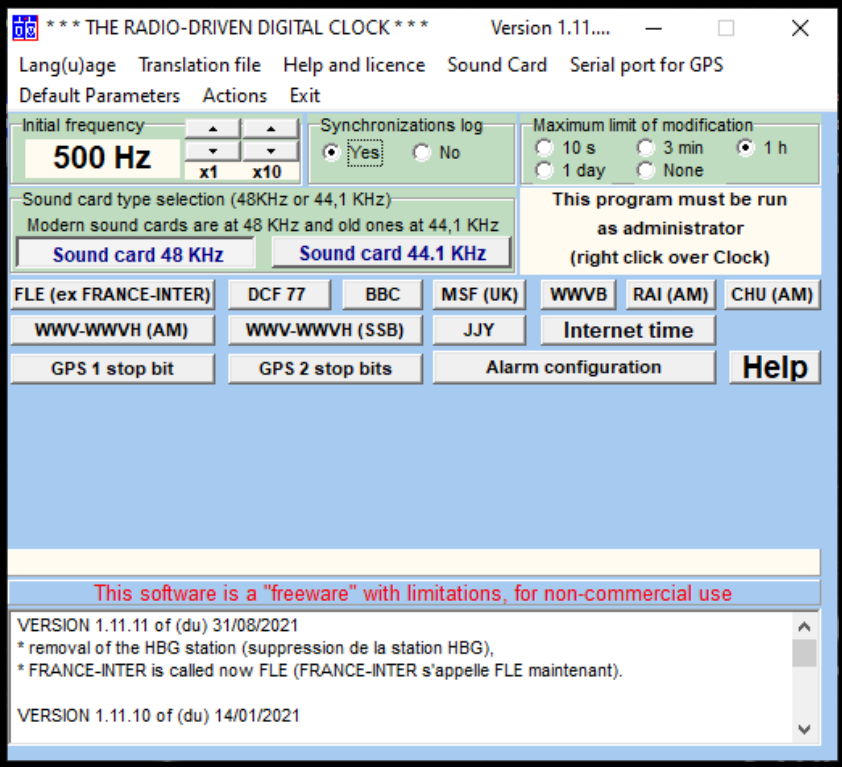
Keeping your computer time accurate

- If you run FT8, you will notice some people are transmitting way out of their time slots. Their computer oscillators allowed the clocks to drift and have no NTP source to correct the clock. Here are some options to prevent this:
- Set the computer clock by tuning to WWV and manually sync the clock.
- Use a software program like *MultiPSK & Clock* and a sound card to decode WWV. Might work with acoustic coupling in a quiet environment.
- Get a USB GPS device for your computer and run software like *NMEATime*.
- Buy or build a dedicated NTP server.
- Turn one computer into a *Simple NTP* (SNTP) server using something like *Dimension 4* software and point all other computers on the network to it.

Keeping your computer time accurate

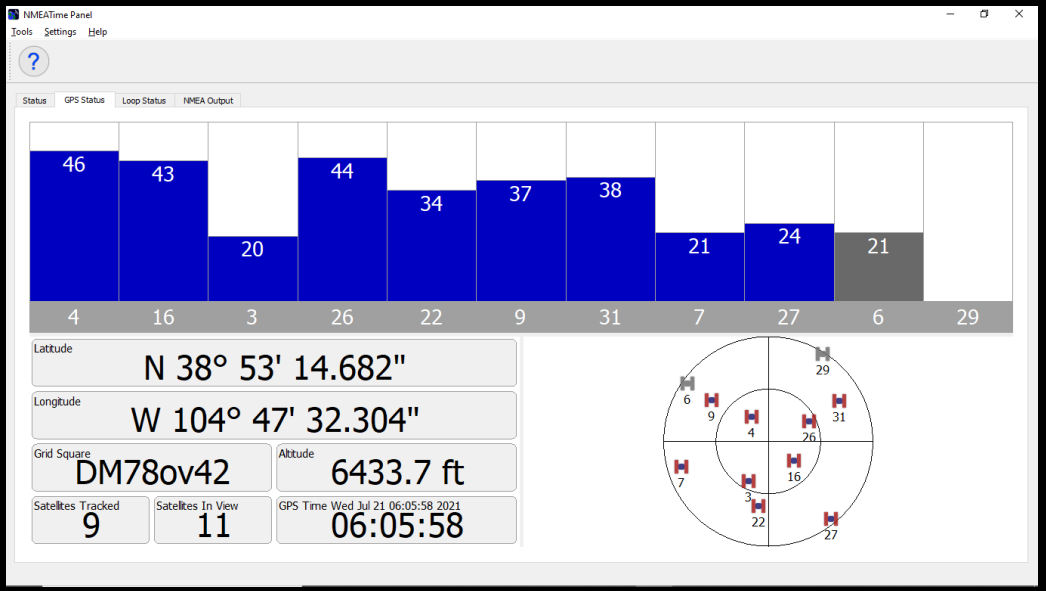


Dimension 4



Multi PSK & Clock

Keeping your computer time accurate



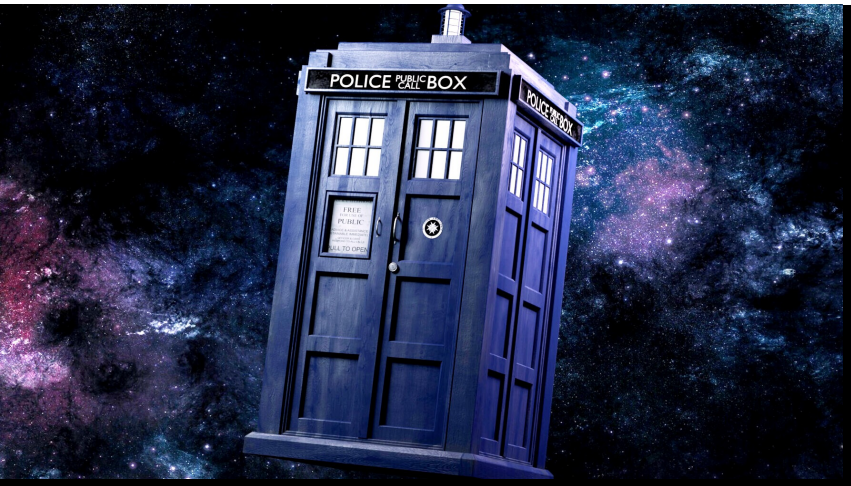
Clockwise from upper left:
- Commercial NTP Server with Rubidium Oscillator
- GPS USB Puck
- Small NTP Server
- NMEATime

Official Time and Frequency Sources

- ***National Institute of Standards and Technology*** (NIST) including the facility in Boulder, CO and the WWV/WWVB transmitters north of Fort Collins, CO.
- ***US Naval Observatory, Washington DC.*** Master Clock for the DoD and the US. Also, the official residence of the Vice President.
- ***US Naval Observatory, Schriever SFB, CO.*** Alternate Master Clock for the DoD and US and key to GPS operations.

Official Time and Frequency Sources

- The USNO Alternate Master Clock at Schriever Space Force Base has:
  - Three Hydrogen MASERS, each in special temperature controlled rooms
  - Twelve Cesium Beams
  - Two Atomic Fountains
- Stays within sub-nanosecond sync to the USNO Master Clock in D.C.



Parting Shot

A person with one watch knows what time it is.

A person with two watches is never sure.