TIME DIFFERENCES IN CHARTED SOLAR OBSERVATIONS AT HIGH FREQUENCIES

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1. Introduction

Several observers have contacted me to ask why their charted solar observations at high frequencies (HF) show different times for the same phenomena recorded by other observers. They suspect that their location, the ionosphere or something else causes different propagation times, thus accounting for the differences, but they are wrong. The real reason is incorrect time-of-day clock settings in their PCs that are collecting the data. Before discussing that I will first discuss the things that are sometimes blamed for the time differences and show why they have no effect.

2. Radio propagation

There are numerous causes of time differences, but propagation time difference due to location on Earth is not one of them. Radio waves in a medium propagate at the speed of light in that medium. For most of the distance between the Sun and Earth, the medium essentially is a vacuum and the speed of light is close to 3×10^8 m/s (3×10^5 km/s). By the time the radio waves associated with a solar emission reach Earth they are plane waves. Those plane waves arrive at different points on Earth at different times. The question is how much difference is there?

To answer that question, look at figure 1, which represents the worst-case situation for two observers. One observer is at the equator with the Sun is directly overhead and the other observer also is at the equator but the Sun is just setting or rising. The path length difference for the plane wave equals Earth's radius, about 6400 km (the observers do not have to be at the equator for this to be true, but I will keep it simple).

Assuming no ionospheric effects, the difference in propagation time would be (distance) / (speed of light) = (6400 km) / (3×10^5 km/s) = 0.021 s = 21 ms, a pretty small number and not discernible on a chart such as Radio-SkyPipe.

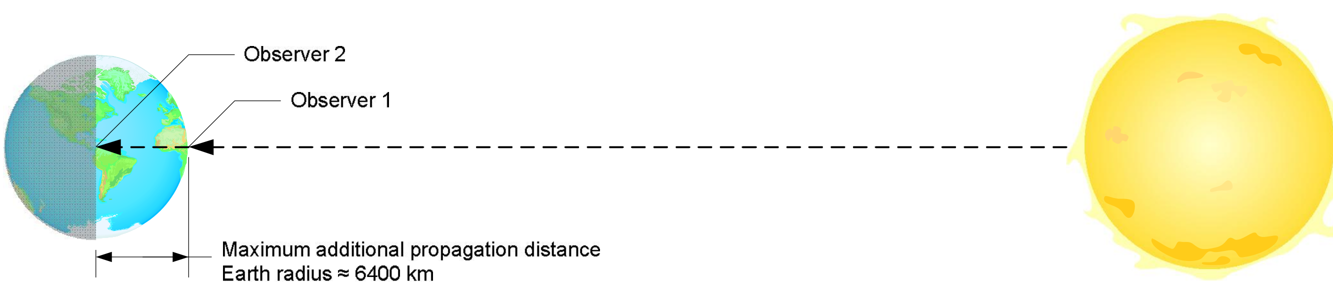


Figure 1 – Worst-case difference in propagation distance for solar radio waves is Earth's radius.

3. Frequency effects

Many solar bursts are Type III, which exhibit a fast radio sweep, or drift, from a beginning high frequency to an ending low frequency. For our purposes, the propagation speed toward Earth is the same for all radio frequencies. However, the time of a burst measured at a discrete frequency on a Radio-SkyPipe chart will depend on the drift rate and the frequency being measured. Generally, the burst will occur earlier on the chart at a higher frequency than a lower frequency. Therefore, two observers recording the same Type III burst at two different frequencies will report two different times for the start, peak and end of the burst.

For a Type III burst, the time difference between the peaks at two frequencies can be quite variable, usually with a higher drift rate at higher frequencies. Reported drift rates in one reference [Kundu] give 1 to 10 MHz/s in the 18 to 35 MHz range. I have measured 10 seconds for the drift from 27 and 19 MHz, or 0.8 MHz/s. Therefore, two observers with 1 MHz difference in observing frequency may see roughly 0.1 to 1 second difference for a given fast-sweep radio burst.

Not all bursts are fast sweeps. For Type II slow radio sweep bursts and bursts with a lot of frequency and time complexity, there is no easy way to compare events on Radio-SkyPipe charts unless the receivers involved in the measurement are all tuned to the same frequency and have the same bandpass characteristics.

Ionospheric effects

It is well known that the ionosphere affects radio wave propagation, especially at HF. A high electron density ionosphere will delay a noise-like emission more than a low-density ionosphere. This effect is frequency dependent. However, the ionosphere is, at most, about 1000 km above Earth's surface, and this distance is very small compared to the roughly 150 x 10^6 km distance from Sun to Earth. The delay (or more accurately, the group delay) is on the order of tens of nanoseconds and can be ignored for our purposes (for Global Positioning System, GPS, ionospheric effects are significant for precision navigation but we are not navigating with Radio-SkyPipe). Probably the most noticeable ionospheric effect is the apparent alteration of the solar burst shape as recorded at different locations. This shape difference can be interpreted (or misinterpreted) as a time difference in some cases. It usually is easier to compare burst times by examining the beginning and ending of the burst as seen on each chart.

4. Receiver effects

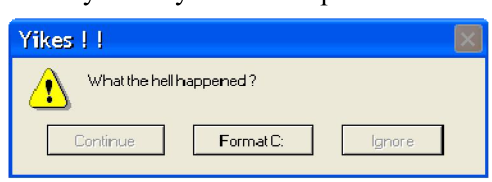
The burst shape as recorded on Radio-SkyPipe depends somewhat on the receiver being used and how it is setup. However, the burst times recorded will not be materially different particularly with high-frequency (HF) receivers and setups typically used by amateur radio astronomers.

5. Software effects

How well Radio-SkyPipe keeps time depends on the timing source it is setup to use – Windows Timer or Soundcard (on RSP, go to Options menu – Timing tab – Timing Source). The soundcard option usually provides the best overall timing accuracy. As would be expected, some soundcards are much better in this regard than others, and some soundcards provide degraded accuracy at certain sample rates. However, as far as I know, the differences amount to small fractions of a second. Also, the Windows operating system itself does not keep or report perfect time but, again, I do not believe the errors are significant unless you are worried about sub-millisecond accuracy.

6. The main problem

Now we get to the main source of time difference in Radio-SkyPipe charts of solar emissions: PC real-time clock (time-of-day clock) error. If you read my article in the April-May 2012 issue of ***Radio Astronomy*** [Reeve], then you know how to accurately set and maintain your PC clock. It may be necessary to set your clock update rate to 5, 10 or 15 minutes. You cannot depend on a clock that is set only once every week or month. But what about the other observers' PCs, the observers you are comparing your chart to? Are their PC clocks accurate? Of course, that is not always easy to answer because they may have no idea how to set their PC clock accurately or maybe the other observers says their clocks are right-on-the-money when they really are not.



7. Example

Figure 2 shows two Radio-SkyPipe charts provided by an observer who wishes to remain anonymous. Although the burst shapes shown on the two charts are different, we can say the main feature has a time difference of around 30 seconds. There really is only one way such an error can occur and that is due to real-time clock error on one or both PCs.

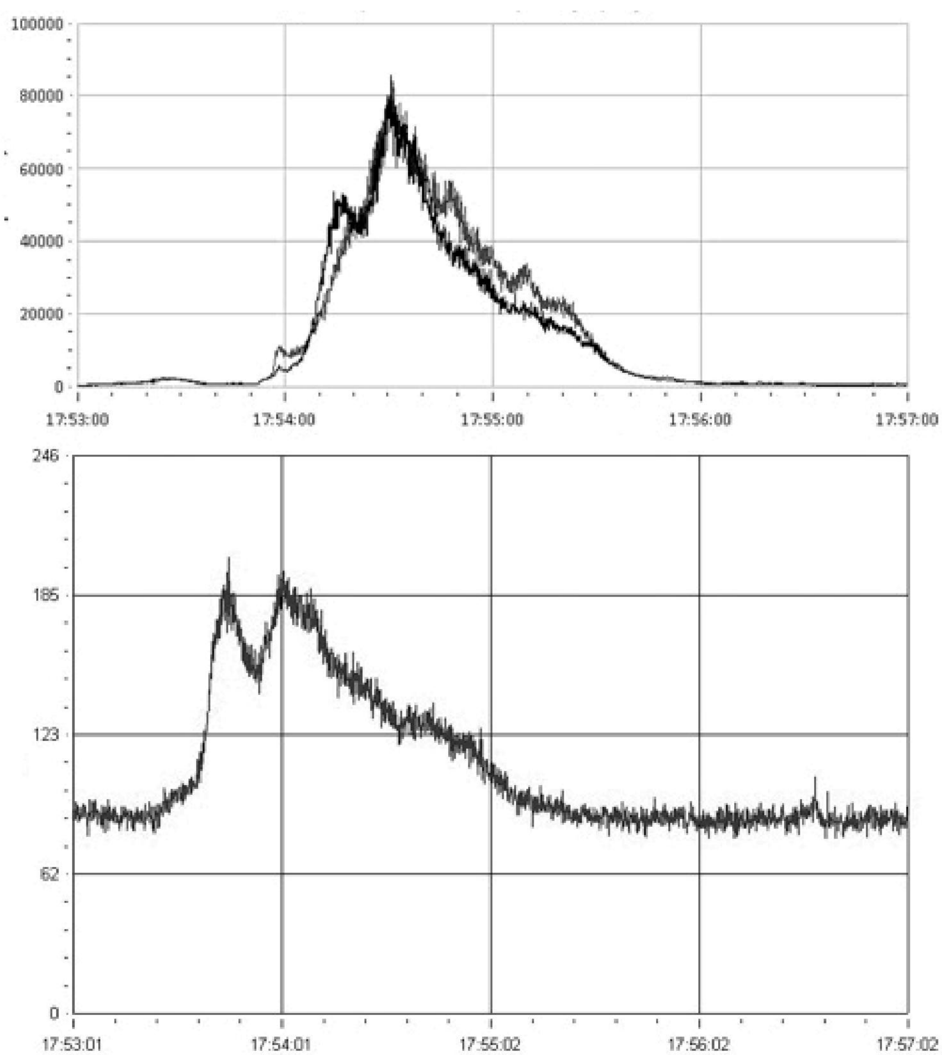


Figure 2 ~ Comparison of the same solar burst recorded at two different locations on Earth, Florida and Oklahoma. The time difference of the main feature is about 30 seconds, much too large to be blamed on propagation or any other external phenomena. The time shown on the upper trace is the most accurate.

8. Conclusions

The importance of time accuracy in our observations cannot be overstressed, and there really are no excuses for any significant error. Observers do not need to blame their location or ionospheric clouds and waves for observed time differences. They do need to pay attention to the time-of-day clock on their PCs and their collaborator's PCs.

9. References

[Kundu] Kundu, M., Solar Radio Astronomy, Interscience Publishers, John Wiley & Sons, 1965
[Reeve] Reeve, W., Maintain Your Time, *Radio Astronomy*, April-May 2012