Picoseconds or ppm?

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An interesting myth has made its way into the market recently: that a 48000.000Hz clock makes your audio sound better than a 48000.100Hz one. Okay, that's not the way they put it. Nobody can keep a straight face and say that. Instead they say that your audio improves when you lock it to an atomic standard. For some reason people find that more convincing. Why? Semantics!

Accuracy? Stability?

Atomic clocks are "accurate". Some are only a second off in a century (about three billion seconds). That's the sort of thing they were designed for. Does that imply that they are only one three-billionth of a second off in one second? Not at all. When a clock runs one millisecond late during one second and one millisecond early during the next, it's basically correct again. So long as these short term errors don't accumulate over time, they do not disqualify the clock as a timepiece. But you will agree that it would not merit the name "stable". A clock that is one second off every day could still manage to slice every second into tiny slivers that are just perfectly equal. *Accuracy and stability are two very different things.* People make and use rubidium standards for audio simply because it is very easy to confuse accuracy with stability so it sounds all to plausible that accurate clocks are better for audio. Add to that the tech-appeal of laboratory equipment and you've got a story that spreads like wildfire.

What does it sound like when an audio clock is 10ppm off?

Well, it makes the recording sound as though the speed of sound during the recording were 10ppm faster or slower. The speed of sound increases by 0.17% per °C (or some 0.1% per °F). So a static 10ppm error sounds like the temperature in the recording hall was 0.0057°C (0.01°F) higher or lower. People who are trying to convince you that those 10ppm matter are actually saying that a temperature difference of 0.0057°C during a musical performance makes all the difference.

Seriously: the best trained ears can detect pitch differences only down to about 700ppm. Red book specifies that CD players be no more than 200ppm off and the CC1 is typically accurate to 2ppm to insure any thinkable downstream device will lock. Tighter accuracy specs serve no purpose as audio is concerned.

What does it sound like when an audio clock jitters?

Well, to keep the analogy: it sounds like the speed of sound is constantly changing, modulating the sounds and spatial cues that it carries. This ties in well with subjective reports that improved jitter makes it much easier to pick out placement and ambience without having to strain one's ears. We can debate what the smallest amount of audible jitter is, but there can be no doubt that jitter matters infinitely more than whether a clock can be used to keep time for a century. If sound quality matters, the battle to win is reducing jitter. It happens to be much harder than getting absolute precision.

How do rubidium clocks work?

They operate on the fact that if you shine the light from a rubidium lamp through a cell filled with rubidium gas, you get a 0.1% increase in absorption if at the same time you submit the gas to an electromagnetic field oscillating at 6834682610.904324Hz. So you make an oscillator operating at nearly this value and you constantly wiggle (ie. intentionally jitter) the frequency around to home in on this tiny dip. The wiggling is needed because if your oscillator wanders out of the dip, you don't know which way it went.

The oscillator already has to be quite good so a very high quality crystal oscillator is used followed by a multiplier or a synthesizer (see Figure 2 for an example of how a synthesizer works). The same crystal oscillator feeds another synthesizer that puts out 10MHz. Alternatively the crystal oscillator can put out 10MHz directly and a more complex synthesizer/multiplier feeds the rubidium gas cell.

You may have been told that rubidium standards necessarily deliver 10MHz. That's not quite the case. When you buy one of those tin cans from a lab equipment supplier it puts out 10MHz but that's only because laboratories have standardized on that number. After all, 6834682610.904324Hz isn't a very useful frequency. So, off-the-shelf lab units synthesize 10MHz.

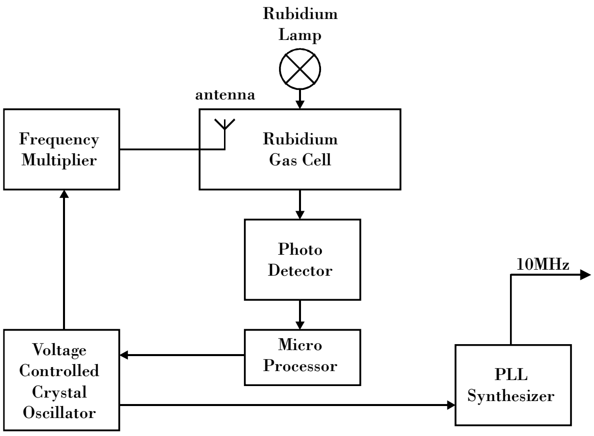

Figure 1: Block diagramme of a typical rubidium frequency standard

Unfortunately, a 10MHz frequency standard doesn't improve things. None of the usual audio rates are simply related to 10MHz. It would have been infinitely more sensible to derive audio rates, or multiples, straight from the rubidium gas cell instead of generating 10MHz first. When a frequency standard sold by an audio company to the audio market puts out 10MHz this is simply because it's a rebadged OEM rubidium standard. This requires yet another synthesizer to get to a standard audio rate:

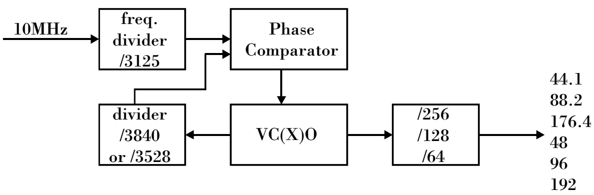

Figure 2: Audio word clock generator with 10MHz reference input. This whole structure is called a PLL synthesizer. Something similar is used in the output stage of Figure 1.

Because of the fact that the two frequencies are not simply related there is a lot of scope for intermodulation. The greatest common denominator between 44.1kHz and 10MHz for instance is 100Hz. It is exceedingly difficult to make a synthesizer with such a ratio that doesn't have significant jitter products at 100Hz intervals. If the aim of the undertaking is to minimize jitter, bringing in a 10MHz laboratory standard is a surefire way of making things much more complicated and much more expensive.

Do atomic clocks have low jitter?

The crystal oscillator used to probe the rubidium cell is top rate. It has to be because if it had significant jitter the photo cell wouldn't get a stable reading. So if such an oscillator were used alone, without the rubidium and without an extra synthesizer to get to 10MHz, jitter would be superb. That's not the case and the output spectrum is rarely clean. It's only centered at a very precise frequency, that's all. That's their only purpose.

I like my CC1. Will attaching an atomic standard make it better?

No. The lowest jitter clock you can ever get is a really good crystal oscillator that puts out the frequency you want (or an integer multiple) directly. This is what the CC1 does. Besides low jitter, the CC1's great strength is the slave mode. The CC1's jitter performance does not change when locked to a jittery source.

I run a broadcast facility so I have an atomic standard to sync the house. Will a CC1 improve the quality of the clock?

Absolutely. That is what the CC1 is designed to do: to generate a low jitter clock, either stand-alone or synchronized to an external source.