Graphical picture of the options for the redefinition of the SI second

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Following the significant advancements in optical clocks, the time and frequency metrology community has been actively discussing the redefinition of the second. At the General Conference on Weights and Measures in 2022, there was a request for a proposal on how to redefine the SI second to be presented at the 2026 conference, in anticipation of its redefinition at the 2030 conference.[1].

Currently, the Consultative Committee for Time and Frequency (CCTF) is evaluating three approaches for this redefinition:

1. Selecting a single atomic transition to replace the cesium hyperfine transition.
2. Utilizing multiple transitions and defining the frequency as a weighted geometric mean of those transition frequencies.[2]
3. An indirect definition by fixing the value of a physical constant to a defined value.

Frequency measurements of atomic transitions allows us to determine the most likely frequency ratios among multiple transitions. For N atomic transitions, we experimentally determine $N-1$ of the most likely frequency ratios, each with its own uncertainty. These experiments constrain the possible frequency values in N-dimensional space to a single line originating from the origin. This line represents the set of all possible frequency combinations that conform to the measured ratios. Consider the case for $N=2$, illustrated in Figure 1. Defining the frequency $\nu_1 = 50$ as per option 1 can be represented graphically by a vertical line ***a***, intersecting with the constraint slope to find the frequency ν_2. This definition need not be linear, provided it intersects with the slope. The curve ***b*** represents option 2, with the formula $\nu_1^{0.5}\nu_2^{0.5} = 50^{0.5}40^{0.5}$, illustrating the concept graphically. This visualization helps clarify the distinction between sub-options 2.1 and 2.2. Option 2.1 keeps the definition curve static, with revised frequencies moving along the original curve. Conversely, option 2.2 allows for adjusting the weights and adding transitions, effectively creating a new definition curve. The intersection and subsequent curve are defined by the newly selected weights and transitions, demonstrating the increased flexibility in redefining the second.

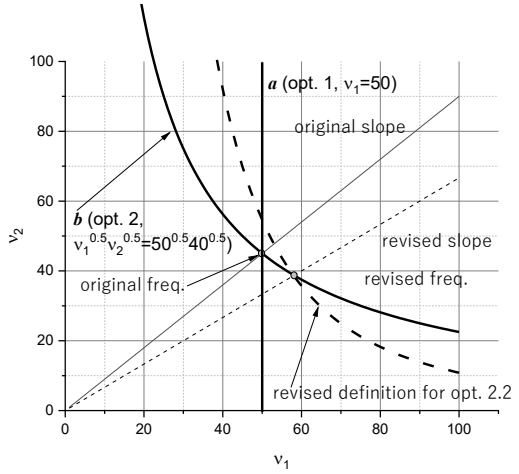

Fig. 1: Graphical picture of the option 1, 2.1, and 2.2 for the definition of the second.

[1] N. Dimarcq *et al.*, "Roadmap towards the redefinition of the second" Metrologia **61**, 012001, 2024.

[2] J. Lodewyck, "On a definition of the SI second with a set of optical clock transitions" Metrologia **56**, 055009, 2019.