Eigenfrequency of a Schumann Resonance

Mert Yucemoz[1]

[1]University of Bath

November 26, 2022

Abstract

There are different numerical models, such as the transmission-line matrix model or partially uniform knee model used to predict Schumann radiation. This report introduces a new idea, and reasoning to the previously stated idea of locating Schumann resonances on a single particle's radiation pattern using a Golden ratio and their Octave, triad relationship. In addition, this different prediction method for Schumann resonances derived from the first principle fundamental physics combining both particle radiation patterns and the mathematical concept of the golden ratio spiral that expands at the rate of the golden ratio. The idea of golden ratio spiral allows locating Schumann resonant frequencies on particle's radiation patterns. The Octaves allows us to predict the magnitude of other Schumann resonances on the radiation pattern of a single accelerated charged particle conveniently by knowing the value of the initial Schumann resonant frequency. In addition, it also allows us to find and match Schumann resonances that are on the same radiation lobe. Furthermore, it is important to find Schumann octaves as they propagate in the same direction and have a higher likelihood of wave interference. Method of Triads together with Octaves helps to predict magnitude and direction of Schumann resonant points without needing to refer to a radiation pattern plot. As the golden ratio seems to be part of the Schumann resonances, it is helpful in understanding to know why this is the case. The main method used in the reasoning of the existence of golden ratio in Schumann resonances is the eigenfrequency modes, $ \sqrt{n(n+1)} $ in the spherical harmonic model. It has been found that eigenfrequency modes have two a start off points, $ n_0 = 0 $ or $ n_0 = \frac{\sqrt{5}-1}{2} $ where the non-zero one is exactly the golden ratio. This allows to extend the existing eigenfrequency modes to $ \sqrt{(n_0+n)^2+(n_o+n)} $ in order to explain why golden ratio exist within Schumann resonances.

Eigenfrequency of a Schumann Resonance

Mert Yücemöz[1]

[1]University of Bath

Key Points:

- There is a Golden ratio, $\frac{\sqrt{5}-1}{2}$ eigenfrequency offset, n_0 describing ionospheric changes in the sequence of $\sqrt{n(n+1)}$ eigenfrequency mode orders.
- Complete eigenfrequency modes starts off at one of the two (0 and $\frac{\sqrt{5}-1}{2}$ intersection points.
- Complete eigenfrequency mode with the offset is $\sqrt{(n_0+n)^2+(n_o+n)}$. Where, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$.

Corresponding author: Mert Yucemoz, `m.yucemoz@bath.ac.uk`

Abstract

There are different numerical models, such as the transmission-line matrix model or partially uniform knee model used to predict Schumann radiation. This report introduces a new idea, and reasoning to the previously stated idea of locating Schumann resonances on a single particle's radiation pattern using a Golden ratio and their Octave, triad relationship. In addition, this different prediction method for Schumann resonances derived from the first principle fundamental physics combining both particle radiation patterns and the mathematical concept of the golden ratio spiral that expands at the rate of the golden ratio. The idea of golden ratio spiral allows locating Schumann resonant frequencies on particle's radiation patterns. The Octaves allows us to predict the magnitude of other Schumann resonances on the radiation pattern of a single accelerated charged particle conveniently by knowing the value of the initial Schumann resonant frequency. In addition, it also allows us to find and match Schumann resonances that are on the same radiation lobe. Furthermore, it is important to find Schumann octaves as they propagate in the same direction and have a higher likelihood of wave interference. Method of Triads together with Octaves helps to predict magnitude and direction of Schumann resonant points without needing to refer to a radiation pattern plot. As the golden ratio seems to be part of the Schumann resonances, it is helpful in understanding to know why this is the case. The main method used in the reasoning of the existence of golden ratio in Schumann resonances is the eigenfrequency modes, $\sqrt{n(n+1)}$ in the spherical harmonic model. It has been found that eigenfrequency modes have two a start off points, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$ where the non-zero one is exactly the golden ratio. This allows to extend the existing eigenfrequency modes to $\sqrt{(n_0+n)^2 + (n_o+n)}$ in order to explain why golden ratio exist within Schumann resonances.

1 Introduction

Schumann resonances are extremely low-frequency waves that bounce back and forth between the ground and the ionosphere of the earth. Schumann resonances originate mostly from lightning discharges. However, a contribution can also be from outer space. Schumann resonances were first predicted by Schumann in 1952 (Schumann, 01 Feb. 1952) and experimentally observed in 1960 (Balser & Wagner, 1960). In addition, Schumann resonances can be predicted, with numerical methods such as the partially uniform knee model (Pechony & Price, 2004) or with the Transmission Line Matrix model (Morente et al., 2003). Recently, Golden ratio, Golden ratio spiral, and rectangle all were combined and introduced to be capable of finding the magnitudes and locating Schumann resonances on a single particle radiation pattern (Yucemoz, 2020). The Golden ratio spiral is quite an important method, as it enables to know the location of Schumann resonant frequencies on a radiation pattern of a single charged particle that is consists of many frequencies from low to ionizing part of the spectrum. Furthermore, as an expansion to the idea of locating Schumann resonances using the Golden ratio spiral, the method of electromagnetic octaves was introduced. Octaves exist in standing transverse waves and sound waves in the form of music discovered by the Pythagoras using the Pythagorean ratios (Crocker, 1964). One octave between the two waves is double frequency apart from each other, but they sound the same (Schellenberg & Trehub, 1994). In terms of an accelerated relativistic particle, radiation is emitted in the form of a forward-backward radiation pattern. This radiation pattern consists of lobes that are different from each other due to physical Bremsstrahlung and Doppler asymmetries (Yucemoz & Füllekrug, 2020). These lobes are closed loops, and they are bound to the charged particle. The standing transverse octave waves method predicts only the values of Schumann resonant frequencies that are located on the same radiation lobe as the input Schumann frequency point. These Schumann points are known as octaves of the input Schumann values. Triads are an extension of octaves. They help predict and understand Schumann resonant pairs and where they are located on a relativistic radiation pattern without having to calculate Octave values. As the golden ratio seems to be part of the Schumann resonances, it is helpful in understanding to know why this is the case. The main method used in the reasoning of the existence of golden ratio in Schumann resonances is the eigenfrequency modes, $\sqrt{n(n+1)}$ in the spherical harmonic model. The simple form spherical cavity model relates Schumann frequency to the eigenfrequency modes, $\sqrt{n(n+1)}$ via $f_n = \frac{c}{2\pi R}\sqrt{n(n+1)}$. Where R is the radius of the planet, c is the speed of light, and n is the eigenfrequency mode order, $n = 1, 2, 3, ...$ This definition, excludes the ionosphere conductivity and height (Simões et al., 2012, equation 1). A more comprehensive spherical cavity model including ionosphere conductivity and height is given in (Simões et al., 2012, equation 2). In this contribution, it has been found that eigenfrequency modes have two a start off points, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$ where the non-zero one is exactly the golden ratio. This allows to extend the existing eigenfrequency modes to $\sqrt{(n_0+n)^2+(n_o+n)}$ in order to explain why golden ratio exist within Schumann resonances. Hence, new spherical cavity model can be re-written and extended as, $f_n = \frac{c}{2\pi R}\sqrt{(n_0+n)^2+(n_o+n)}$. Where, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$. The Golden ratio, $\frac{\sqrt{5}-1}{2}$ eigenfrequency offset, n_0 describes ionospheric changes.

2 Analysis of Spherical Harmonics Model of Schumann Resonances for Golden Ratio

Previously, the relationship between Schumann resonances and the golden ratio has been introduced. Schumann resonance notes from A to G on the radiation pattern are located using the Golden ratio spiral (Yucemoz, 2020).

This section investigates and introduces new idea to why Schumann resonances might scale with the Golden ratio. In addition, existing eigenfrequency modes, n and $\sqrt{n(n+1)}$ have been corrected by identifying, locating and incorporating two intersection points (0 and $\frac{\sqrt{5}-1}{2}$). These two intersection points are displayed in Figure 1. New complete definition for Eigenfrequency mode is $\sqrt{(n_0+n)^2+(n_o+n)}$ Where, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$.

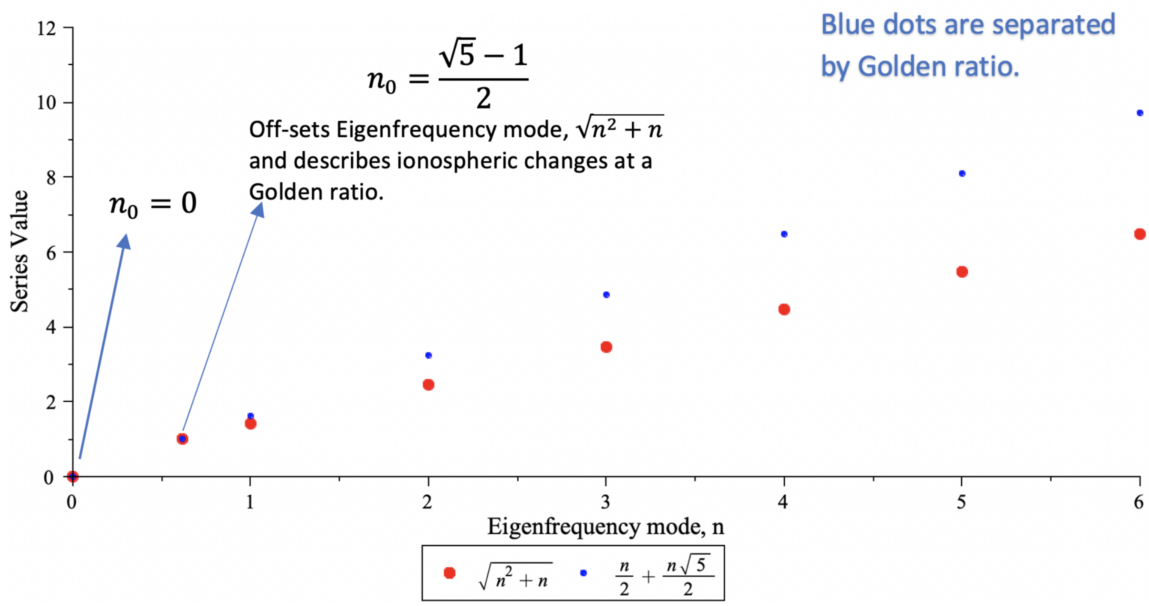

Figure 1. Two intersection points (0 and $\frac{\sqrt{5}-1}{2}$. The new complete definition for Eigenfrequency mode is $\sqrt{(n_0+n)^2+(n_o+n)}$ Where, $n_0 = 0$ or $n_0 = \frac{\sqrt{5}-1}{2}$. Blue line defines the golden ratio and multiples of golden ratio that increases with n. Red line defines the eigenfrequency modes in spherical harmonics model of Schumann resonances. As can be seen, second, non-zero intersection point of red and blue line is at exactly golden ratio, $\frac{\sqrt{5}-1}{2}$. The $n_0 = 0$ describes Schumann resonant frequency excluding ionospheric changes. Whereas, $n_0 = \frac{\sqrt{5}-1}{2}$ considers ionospheric changes at the value of Golden ratio.

Value of the second intersection point shown in figure 1 is found to be $\frac{\sqrt{5}-1}{2}$. This value is the definition of a golden ratio.

The golden ratio, ϕ is written in quadratic form as $\phi^2 - \phi - 1 = 0$. The roots of the quadratic equation can be found by taking, $a = 1, b = -1, c = -1$. Therefore, golden ratio have two values of $\phi = \frac{1\pm\sqrt{5}}{2}$ which are inverse of each other (as $\phi - 1 = \frac{1}{\phi}$).

3 Discussion & Conclusion

The new complete definition for eigenfrequency mode, $\sqrt{(n_0+n)^2+(n_o+n)}$ means that Schumann resonant frequencies can exist with the scale of golden ratio. Definition of eigenfrequency mode order, n remains the same and have values of $n = 1, 2, 3, ...$ If the start off is at $n_0 = 0$, the Schumann resonant frequency description exclude ionospheric changes. However, if the start off is at $n_0 = \frac{\sqrt{5}-1}{2}$, ionospheric changes at the value of Golden ratio and Schumann resonant frequencies scale with a Golden ratio. This can be shown as, $\sqrt{(\frac{\sqrt{5}-1}{2}+n)^2+(\frac{\sqrt{5}-1}{2}+n)}$. When $n = 1$, eigenfrequency mode is exactly equal to the value of golden ratio, ϕ. Hence, $\sqrt{(\phi)^2+(\phi)}$ where, ϕ is the golden ratio. As value of n increases, eigenfrequency modes are the multiples of the golden ratio.

Overall, ionospheric changes are approximately at a value of Golden ratio.

Acknowledgments

I would like to thank my supervisor Dr.Martin Füllekrug for all the support. My family for their support and good wishes. EPSRC and MetOffice sponsor my PhD project under contract numbers EG-EE1239 and EG-EE1077. The Maple worksheets used to simulate the radiation patterns with the Golden Ratio spiral to locate the Schumann resonances are openly available from the University of Bath Research Data Archive at https://doi.org/10.15125/BATH-00914.

References

Balser, M., & Wagner, C. A. (1960). Observations of earth–ionosphere cavity resonances. *Nature*, *188*(4751), 638–641. Retrieved from `https://doi.org/10.1038/188638a0` doi: 10.1038/188638a0

Crocker, R. L. (1964). Pythagorean mathematics and music. *The Journal of Aesthetics and Art Criticism*, *22*(3), 325–335. Retrieved from `http://www.jstor.org/stable/427236`

Morente, J. A., Molina-Cuberos, G. J., Portí, J. A., Besser, B. P., Salinas, A., Schwingenschuch, K., & Lichtenegger, H. (2003). A numerical simulation of earth's electromagnetic cavity with the transmission line matrix method: Schumann resonances. *Journal of Geophysical Research: Space Physics*, *108*(A5). Retrieved from `https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2002JA009779` doi: 10.1029/2002JA009779

Pechony, O., & Price, C. (2004). Schumann resonance parameters calculated with a partially uniform knee model on earth, venus, mars, and titan. *Radio Science*, *39*(5), 1-10.

Schellenberg, E. G., & Trehub, S. E. (1994). Frequency ratios and the perception of tone patterns. *Psychonomic Bulletin & Review*, *1*(2), 191–201. Retrieved from `https://doi.org/10.3758/BF03200773` doi: 10.3758/BF03200773

Schumann, W. O. (01 Feb. 1952). Über die strahlungslosen eigenschwingungen einer leitenden kugel, die von einer luftschicht und einer ionosphärenhülle umgeben ist. *Zeitschrift für Naturforschung A*, *7*(2), 149 - 154. Retrieved from `https://www.degruyter.com/view/journals/zna/7/2/article-p149.xml` doi: https://doi.org/10.1515/zna-1952-0202

Simões, F., Pfaff, R., Hamelin, M., Klenzing, J., Freudenreich, H., Béghin, C., … Yair, Y. (2012, apr). USING SCHUMANN RESONANCE MEASUREMENTS FOR CONSTRAINING THE WATER ABUNDANCE ON THE GIANT PLANETS—IMPLICATIONS FOR THE SOLAR SYSTEM's FORMATION. *The Astrophysical Journal*, *750*(1), 85. Retrieved from `https://doi.org/10.1088/0004-637x/750/1/85` doi: 10.1088/0004-637x/750/1/85

Yucemoz, M. (2020). Locating schumann resonant frequencies on a single particle radiation patterns using golden ratio spiral. *Earth and Space Science Open Archive*, 8. Retrieved from `https://doi.org/10.1002/essoar.10504424.1` doi: 10.1002/essoar.10504424.1

Yucemoz, M., & Füllekrug, M. (2020). Asymmetric backward peaking radiation pattern from a relativistic particle accelerated by lightning leader tip electric field. *Earth and Space Science Open Archive*, 28. Retrieved from `https://doi.org/10.1002/essoar.10503599.1` doi: 10.1002/essoar.10503599.1