New Method in Calculating Schumann Resonances and Finding Octave relationship between the Schumann Resonances Using Electromagnetic Wave Octaves

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Key Points:

- New idea to find Schumann resonant points on the same radiation lobe using electromagnetic wave octaves.
- There is a maximum of two Schumann pairs found on a single radiation lobe (Front bottom lobe).
- Schumann octave resonances can only exist on the same radiation lobe provided that radiation lobes are different from each other.

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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 method build on the previously stated idea of locating Schumann resonances on a single particle's radiation pattern using a Golden ratio. 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 Golden ratio. Moreover, extending the idea of ratios to a specific ratio called octaves used in standing waves that identify the identical sounding notes with different frequencies. Knowing the value of initial Schumann resonant frequency, this method allows us to predict the magnitude of other Schumann resonances on the radiation pattern of a single accelerated charged particle conveniently. In addition, it also allows us to find and match Schumann resonances that are on the same radiation lobe, which is named electromagnetic Schumann octaves. Furthermore, it is important to find Schumann octaves as they propagate in the same direction and have a higher likelihood of wave interference.

Plain Language Summary

In music, octave defines two notes that sound similar but differ in wave frequency. When a particle accelerates, it radiates energy in different shapes as closed lobes. There are specific frequencies on this radiation geometry that bounce back and forth around the Earth between the ground and the ionosphere layer. These frequencies are known as Schumann frequencies. In terms of Schumann resonances of different frequencies, octave defines Schumann frequencies that lie on the same lobe of the radiation pattern and that are octaves apart from each other where one octave is double the initial Schumann resonant frequency. By using this new electromagnetic octave method, Schumann resonances propagating in the same direction can be determined. This is important as they also possess a high likelihood of wave interference.

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 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 are 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. Hence, Schumann points on a radiation pattern of a particle can be modeled with the standing transverse octave waves. This method cannot provide any information about the location of the Schumann resonant frequencies as the Golden ratio spiral method. However, as an extension, the standing transverse octave waves method provides more meaning and information about the Schumann points that are predicted by the Golden ratio spiral. 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. In summary, knowing a Schumann resonant frequency value on a radiation pattern, the equation of standing transverse octave waves method predicts another Schumann frequency point that only exists on the same radiation lobe as the original input Schumann resonant point. Octaves are important as Schumann points on the same radiation lobe propagate in the same direction and, they have a higher likely hood of undergoing wave interference.

2 Theory of Electromagnetic Schumann Resonances Octaves

Octaves applied to the standing transverse waves that are created on the same medium induce and describe the two similar sounds (i.e. musical notes) that are related to each other via octave difference whereas, the only difference is the wave frequency. In addition, one octave describes the double of the initial wave frequency.

Electromagnetic radiation emitted by a single relativistic particle has a forward-backward peaking radiation pattern. This radiation pattern can change in size during the acceleration process. However, it would always be in separate lobes and form a closed loop. This property of the radiation pattern can be used to model the radiation pattern as a standing transverse wave where each, separate, individual radiation lobe has its characteristic shape and property (i.e. Bremsstrahlung and Doppler Asymmetry). As each radiation lobes are different from each other, they can be modeled as different mediums with different properties. Hence, as mentioned above, if two Schumann points are to be called octaves of each other, they must exist on the same radiation lobe.

Mathematically by knowing the frequency value of the initial Schumann resonant point, the value of the other points presented in figure 1 can be calculated and described using equation 1.

$$f_A\left(\frac{n+n\sqrt{5}}{2}\right) = f_n \tag{1}$$

Where, f_A is the frequency of the Schumann note A, n is the number of Golden ratios between Schumann notes A and, the note that is n Golden ratio apart. The frequency of the Schumann resonance on the radiation pattern that is n Golden ratio apart is represented by f_n.

Octave, O between a frequency range can be found by taking the base 2 logarithms of the ratio of maximum to minimum of the Schumann frequency range. Under the initial assumption with the Golden ratio that Schumann resonances scale with the Golden ratio, the ratio of maximum to minimum of a Schumann frequency range can be written as multiples, n of the Golden ratio.

$$O = log_2\left(\frac{n+n\sqrt{5}}{2}\right) \tag{2}$$

To calculate the frequency of the octave Schumann resonance, of a given Schumann resonance frequency, given Schumann frequency should be doubled and multiplied with the number of octaves, O calculated by equation 2.

$$f_O = 2f_{SN}O \tag{3}$$

As the wave frequency and the wave energy are directly proportional to each other, the energy of two-octave Schumann points scales in the same way as twice the octave value.

$$I_O = 2I_{SN}O \tag{4}$$

Where, f_O is a Schumann octave frequency in Hz of a Schumann resonance note (point) f_{SN} in Hz. In addition, radiation intensity of a Schumann octave note is I_O in Js^{-1} and radiation intensity of a Schumann note is I_{SN} in Js^{-1}.

3 Results

In this section, a new method of the electromagnetic Schumann octaves will be used to relate seven Schumann notes in pairs that specifically exist on the same radiation lobe. As can be seen in figure 1, the forward-backward peaking relativistic radiation pattern has four radiation lobes. Each lobe is different from each other due to 2 physical effects of the Bremsstrahlung and the Doppler asymmetries.

The relativistic forward-backward radiation pattern displayed in figure 1 is specific to the Bremsstrahlung process as it incorporates the Bremsstrahlung asymmetry (Yucemoz & Füllekrug, 2020). Schumann resonance notes from A to G on the radiation pattern are located using the Golden ratio spiral (Yucemoz, 2020).

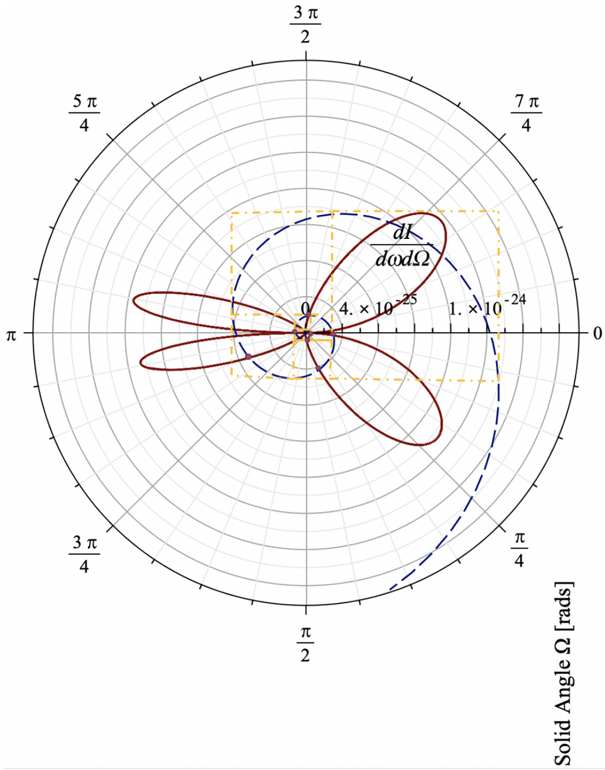

Figure 1. Figure 1 displays a relativistic forward-backward peaking radiation pattern. This radiation pattern is chosen for the octave study as it is the radiation pattern with most Schumann resonant points. Each point on the graphs is named A, B, C, D... starting from the origin and expanding with the spiral. Each named point from A to G is called a Schumann note or a Schumann point.

Taking Schumann note A in table 1 and predicting its Schumann octave pair using equation 4. There are six Golden ratio intervals between Schumann notes A to G. Hence, the value of n is six. Using equation 2, with n being six gives an octave value of 3.279. as presented in table 2. Schumann note radiation intensity, I_{SN} for Schumann note A from table 1 is $\sim 2.15{\times}10^{-26}$. Using input parameters of Schumann note radiation intensity, I_{SN} and octave, O in equation 4, gives a Schumann octave radiation intensity, I_O as $\sim 1.410{\times}10^{-25}$. Therefore, when Schumann octave radiation intensity, I_O is compared with the radiation intensity, I of the all available Schumann notes from A to G, it can be seen that radiation intensity, I of Schumann note, E matches with the predicted octave radiation intensity, I_O. Hence, Schumann notes A pairs up with the Schumann octave note E. In addition, within this pair, A is the lower octave Schumann note whereas, E is the higher octave Schumann note.

Figure 1 confirms that the prediction of electromagnetic Schumann octaves method is correct as Schumann radiation notes (points) A and E exists on the same front, bottom radiation lobe. The same procedure can be applied to the remaining Schumann notes to find their Schumann octave note pairs.

Energy values of each Schumann point and their relation to each other in Figure 1c.	
Schumann Resonance Point (Schumann Note)	Radiation intensity "I" $[Js^{-1}]$ per emitted angular wave frequency "ω" $[rads^{-1}]$ per Solid angle "Ω" $[rad]$ $\frac{dI}{d\omega d\Omega}$
A	$\sim 2.15 \times 10^{-26}$
B	$\sim 3.54 \times 10^{-26}$
C	$\sim 5.632 \times 10^{-26}$
D	$\sim 9.483 \times 10^{-26}$
E	$\sim 1.454 \times 10^{-25}$
F	$\sim 2.217 \times 10^{-25}$
G	$\sim 3.390 \times 10^{-25}$

Table 1. Values of Schumann points A, B, C, D, E and F. Golden ratio of B to A, C to B, D to C, F to E and G to F in figure 1c.

Predicted and Paired Schumann Octave Wave Energies			
The Schumann Octave Pairs	Octave, O value	Number of Golden Ratio, n	Radiation intensity "I_O" $[Js^{-1}]$ per emitted angular wave frequency "ω" $[rads^{-1}]$ per Solid angle "Ω" $[rad]$ $\frac{dI}{d\omega d\Omega}$ of Upper Octave
A $\Rightarrow$ E	3.279	6	$\sim 1.410 \times 10^{-25}$
B $\Rightarrow$ F	3.016	5	$\sim 2.135 \times 10^{-25}$
C $\Rightarrow$ G	2.694	4	$\sim 3.035 \times 10^{-25}$
D $\Rightarrow$ Diminished	2.279	3	$\sim 4.322 \times 10^{-25}$

Table 2. The table displays Schumann resonances and their octave Schumann resonances. The first column of the table gives a pair of Schumann resonances that are octave pairs of each other. The left of the arrow is named as a lower octave, and the right of the arrow is named a higher octave between the octave pairs. To calculate the Schumann resonance octave point, that is on the same radiation lobe as Schumann resonance point A, the first Octave has to be calculated between the Schumann point A and Final Schumann point G. This is known as an octave. Octave is calculated using equation 2 with n of 6 as there is six times the Golden ratio between points A and G displayed in figure 1. Finally, the octave Schumann resonance pair of a Schumann resonances point A, where both share the same radiation lobe, is calculated using equation 4, which is the double of radiation intensity, I of Schumann point A that scales with the number of octaves. The resultant Schumann higher octave radiation intensity, $I_O = 1.410 \times 10^{-25} J$ of A is compared with all radiation intensities determined from the Golden ratio spiral in figure 1, and presented in table 1, it can be seen that Schumann higher octave radiation intensity, I_O is approximately equal to the Schumann radiation intensity of point E in table 1 $I_O \approx I$. This relates point A and E as Schumann octave pairs and means that they should exist on the same radiation lobe, which can be observed in figure 1.

4 Discussion & Conclusion

As can be seen in table 2, all the Schumann octave pairs predicted by the electromagnetic Schumann octaves method are the pairs that in fact, can be found on the same radiation lobe. This can be verified by observing the location of each Schumann note (point) from A to G on the radiation pattern predicted by the Golden ratio spiral presented in figure 1.

Schumann resonant notes (points), can already be found by plotting the Golden ratio spiral and observing which points share the same radiation lobe as displayed in figure 1. However, by using a new method of electromagnetic Schumann octaves, firstly, each Schumann note can be evaluated in terms of magnitude. Secondly, each Schumann note can be paired up, meaning that they share the same radiation lobe and propagate approximately in the same direction without needing to make any plots.

On the other hand, the method of electromagnetic Schumann octaves also reveals that Schumann points (notes) on the same radiation lobe distinguishes from each other following approximately double of octave value. Hence, knowing that two Schumann wave frequencies are double of an octave, O apart from each other means that those Schumann waves are propagating approximately in the same direction. Following the assumption of resembling radiation pattern bound to the charged particle to standing transverse wave produced on the musical instrument, each Schumann note re-presents itself again with a different Schumann frequency on the same radiation lobe. This is the same in the music as the same musical note re-presents itself again on the same string (i.e. guitar) with a different frequency.

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