ESTIMATED LOWER ATMOSPHERIC ELECTROMAGNETIC PROPERTIES

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Estimated Electron Density of Lower Atmosphere per cm^3 Best Estimates : UNALTERED Lower Atmosphere = 500 Ionosphere(D) = ~ 6 to 10,000 (40-80km) Ionosphere(E) = ~ 10,000 to 300,000 (80-140km)	1400
Input Frequency into Plasma in Hz (e.g, ELF Range from 1 to 100)	20
Specify Element and Atomic Mass Number from Periodic Table (e.g., Barium, 137)	Barium 137
Van de Graaf Generator Maximum Rated Output Voltage (Typical = 200,000)	200000
Measured Outdoor Maximum Spark Length from Van de Graaf Generator in inches (Up to 9-10 inches has been measured)	4.0
Elevation of Van de Graaf Generator Above Sea Level in Feet	6500

Estimate Electromagnetic Properties of Lower Atmosphere

Predicted Whistler Frequency in Hertz (Hz) (Right Circular Polarization)	
Predicted Alfven Wave Frequency in Hertz (Hz)	
Computed Plasma Frequency in Kilohertz (KHz)	
Debye Length (radius in meters)	
Plasma Parameter: (No. of Particles in a Debye Sphere)	
Cyclotron Frequency of	

Ion in Hertz (Hz)	
Lower Atmospheric Conductivity Ratio Estimate : Method 1 (This method depends upon knowledge of electron density - achievable with ion counter)	
Lower Atmospheric Conductivity Ratio Estimate : Method 2 (This method depends upon Van de Graaf spark length measurement and voltage rating of generator - achievable)	
Expected Maximum Spark Length from Van de Graaf Generator in Normal Air in inches.	
Atmospheric Conductivity in Ohms^{-1}m^{-1} (* 1E-14) Method 1 (Expected value of conductivity of lower atmosphere = 2E-14)	
Atmospheric Conductivity in Ohms^{-1}m^{-1} (* 1E-14) Method 2 (Expected value of conductivityof lower atmosphere = 2E-14)	

Expected conductivity of lower atmosphere
is now increased by an estimated factor of 3 to 20,
depending upon atmospheric and aerosol conditions.
Note resonant ELF cyclotron frequency of barium
as well as most physiologically imporant ions (e.g, Mg, Ca, K etc.).
This page only considers impact of electron density, not ion density.

Additional Notes:

Assumed Values or Constants for Computations[1]:

Speed of Light (c) : 3E8 m / sec
Mass of an electron (m) : 9.11E-31kg
Magnetic field strength of earth (B) : 5E-5 tesla
Permeability of free space (u_o) : 4 * pi * 1E-7

Electron charge (e) : -1.6E-19 coulombs
Permittivity of free space (e_o) : 8.85E-12 C^2 / N * m^2
Boltzmann's constant (k_b) : 1.38E-23 J / K
Temperature of lower atmosphere (t) : 22 deg C.
Breakdown Voltage (Eb_{max}) (Dielectric Strength) of Normal Air = 3E6 Volts/meter
Work of Ionization of Atmosphere ($W_{ion)}$ = 5E-18 J (~30eV)
T = temperature of lower atmosphere in Kelvin
sigmanorm = conductivity of normal lower atmosphere : 2E-14 ohm^{-1}

1. Predicted Whistler Frequency in Hertz (Hz)(Right Circular Polarization) **Dispersion Relationship**:[2,3]**:**

$k = (w / c) * (1 + (w_{pe}^2 / (w * (w_{ce} - w))))^{1/2}$

and

$f_{hz} = (k * c) / (2 * pi)$

where

w = plasma input frequency in radians

c = speed of light

w_{pe} = plasma frequency in radians

w_{ce} = cyclotron frequency of an electron in earth's magnetic field

k = wave number

f_{hz} = frequency in hertz.

2. Predicted Afven Frequency in Hertz (Hz) Dispersion Relationship:[4]**:**

$k = (w / c) * (1 + ((n_i * m * c^2) / (B^2 / u_o)))^{1/2}$

n_i = electron density per m^3

m = mass of electron

B = strength of Earth's magnetic field

u_o = permeability of free space

3. Plasma Frequency in Radians[5] **:**

$w_{pe} = (n_i * e^2) / (m * e_o)^{1/2}$

e_o = permittivity of free space

4. Debye Length[6] :

$$r_D = ((k_b * T) / m)^{1/2} * (1 / w_{pe})$$

T = temperature in degrees Kelvin

k_b = Boltzmann's constant

5. Plasma Parameter[7] :

$$N_D = ((4 * pi) / 3) * r_D^3 * n_i$$

6. Cyclotron Frequency in hertz[8] :

$$fg = 1.54E3 * (B_{gauss} / A)$$

where A = the mass number of the ion.

B_{gauss} = earth magnetic field strength in gauss.

7. Estimated Lower Atmospheric Conductivity Ratio Estimate (based upon linear relationship of conductivity with n). (METHOD 1):

$$sigma\_ratio_{est} = ni_{est} / ni_{normal}$$

where ni_{normal} is the normal expected electron density per cm3 of the lower atmosphere (~500) and ni_{est} is the estimated electron density of the lower atmosphere. This method requires a knowledge of electron density, and is therefore difficult to achieve.

8. Estimated Lower Atmospheric Conductivity Ratio Estimate - based upon linear relationship of conductivity to the spark length and the exponential relationship of electron generation under breakdown conditions. (METHOD 2):

$$sigma\_ratio_{est} =((e^{alpha * dmeas}) - 1) / ((e^{alpha * dcalc}) - 1) * (d_{meas} / d_{calc})$$

where alpha is the first Townsend coefficient in units of 1 / (m * torr) as is modeled by the following developed equation:

$$alpha = 4.68E-8 * (Eb_{max} / (762 * e^{-.00004h}))^{2.21}$$

where h is the elevation of the Van de Graaf generator above sea level in feet. This equation is developed from a least squares analysis in conjunction with the listed references[15,16,18].

In addition, d_{meas} is the measureed spark length of the Van de Graaf generator in meters within the modified atmosphere and d_{calc} is the theoretical spark length of the Van de Graaf generator of the normal atmosphere.

This work has been developed using a series of references[15, 16, 17], and will be explained in more detail on a separate page related to conductivity investigations and analysis. This method requires only measurements that are available with the use of the Van de Graaf generator.

9. Cyclotron resonant frequency of an electron[9] :

$w_{ce} = ((e * B) / m)$

10. Atmospheric Conductivity (Method 1):

$sigma = (ni^{est} / ni_{normal}) * sigma_{norm}$

11. Atmospheric Conductivity (Method 2):

Refer to page entitled Atmospheric Conductivity II.

References:

1. Gordon J. Coleman, *The Addison-Wesley Science Handbook* (Addison-Wesley Publishers Limited, 1997)
2. R.O. Dendy, *Plasma Dynamics* (Oxford University Press, 2000), 41.
3. William C. Elmore, *Physics of Waves* (Dover, 1985), 10.
4. Dendy, 51.
5. Dendy, 7.
6. Dendy, 10.
7. Dendy, 11.
8. United States Patent # 4686605, Bernard Eastlund, *Method and Apparatus for Altering a Region in the Earth's Atmosphere, Ionosphere, and/or Magnetosphere*, 1987, 6.
9. Alan C. Tribble, *Princeton Guide to Advanced Physics* (Princeton University Press, 1996), 147.
10. Charles Papas, *Theory of Electromagnetic Wave Propagation*, (Dover, 1988), 177.
11. Niels Jonassen, *Breakdown*, Compliance Engineering, www.ce-mag.com/archive/01/01/MrStatic.html, (eq. 4).
12. Jonassen, (eq. 10).
13. Michael Mansfield, *Understanding Physics*, (Wiley and Sons, 1998), 288.
14. Niels Jonassen, *Environmental ESD, Part 1 : The Atmospheric Electric Circuit*, Compliance Engineering, www.ce-mag.com/archive/02/07/mrstatic.html, (eq. 4).
15. Martin A. Ulman, *Lightning*, (Dover, 1984), 204-206.
16. Dwight E. Gray, Ph. D., *American Institute of Physics Handbook*, (McGraw-Hill Book Company, Inc., 1963), 5-138 to 5-140.
17. David R. Lide, *CRC Handbook of Chemistry and Physics, 82ed*, (CRC Press, 2001), 14-19 to 14-20.
18. Claude Irwin Palmer, *Practical Calculus for Home Study*, (McGraw-Hill Book Company, 1924), 151.

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