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Wave Propagation Formulas

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List of 16 Wave Propagation Formulas

Wave Propagation

1) Antenna Beamwidth

$$\text{fx } b = \frac{70 \cdot \lambda}{d}$$

[Open Calculator !\[\]\(a870788d6ed9b8fd294b7654a8c8526b_img.jpg\)](#)

$$\text{ex } 40.15166^\circ = \frac{70 \cdot 90\text{m}}{8990\text{m}}$$

2) Critical Frequency of Ionosphere

$$\text{fx } F_c = 9 \cdot \sqrt{N_{\max}}$$

[Open Calculator !\[\]\(c50c8b7b2cc2cf9ff925edec0ee94c0d_img.jpg\)](#)

$$\text{ex } 1.3\text{E}^9\text{Hz} = 9 \cdot \sqrt{2\text{e}10/\text{cm}^3}$$

3) Electron Density

$$\text{fx } N_{\max} = \frac{(1 - \eta_r^2) \cdot f_o^2}{81}$$

[Open Calculator !\[\]\(f60b7a900783ac3fd531bfd9c111be6d_img.jpg\)](#)

$$\text{ex } 2\text{E}^10/\text{cm}^3 = \frac{(1 - (0.905)^2) \cdot (3\text{e}9\text{Hz})^2}{81}$$



4) Field Strength of Space Wave

$$\text{fx } E = \frac{4 \cdot \pi \cdot E_0 \cdot h_r \cdot h_t}{\lambda \cdot D_A^2}$$

[Open Calculator !\[\]\(cbe80b694ebd74fcfe136a095b608235_img.jpg\)](#)

$$\text{ex } 0.001953\text{V/m} = \frac{4 \cdot \pi \cdot 9990\text{V/m} \cdot 70\text{m} \cdot 32\text{m}}{90\text{m} \cdot (40000\text{m})^2}$$

5) Height of Layer

$$\text{fx } h = \frac{P_d}{2 \cdot \sqrt{\left(\frac{F_{\text{muf}}^2}{f_c^2}\right) - 1}}$$

[Open Calculator !\[\]\(3e2231b1ad3ca8da8658228c00dd08e0_img.jpg\)](#)

$$\text{ex } 1169.985\text{m} = \frac{21714\text{m}}{2 \cdot \sqrt{\left(\frac{(420\text{Hz})^2}{(45\text{Hz})^2}\right) - 1}}$$

6) Line of Sight

$$\text{fx } \text{LOS} = 3577 \cdot \left(\sqrt{h_r} + \sqrt{h_t}\right)$$

[Open Calculator !\[\]\(0d5ec72f61334709c3fc9450209b754f_img.jpg\)](#)

$$\text{ex } 50161.9\text{m} = 3577 \cdot \left(\sqrt{70\text{m}} + \sqrt{32\text{m}}\right)$$



7) Maximum Usable Frequency [Open Calculator](#) 

$$\text{fx } F_{\text{muf}} = f_c \cdot \sqrt{1 + \left(\frac{P_d}{2 \cdot h} \right)^2}$$

$$\text{ex } 419.9999\text{Hz} = 45\text{Hz} \cdot \sqrt{1 + \left(\frac{21714\text{m}}{2 \cdot 1169.985\text{m}} \right)^2}$$

8) Maximum Usable Frequency in F-region [Open Calculator](#) 

$$\text{fx } F_{\text{muf}} = \frac{f_c}{\cos(\theta_i)}$$

$$\text{ex } 420.0435\text{Hz} = \frac{45\text{Hz}}{\cos(83.85^\circ)}$$

9) Normal of Reflecting Plane [Open Calculator](#) 

$$\text{fx } \lambda_n = \frac{\lambda}{\cos(\theta)}$$

$$\text{ex } 103.923\text{m} = \frac{90\text{m}}{\cos(30^\circ)}$$

10) Parallel of Reflecting Plane [Open Calculator](#) 

$$\text{fx } \lambda_p = \frac{\lambda}{\sin(\theta)}$$

$$\text{ex } 180\text{m} = \frac{90\text{m}}{\sin(30^\circ)}$$



11) Phase Difference between Radio Waves

$$\text{fx } \Phi = 4 \cdot \pi \cdot h_r \cdot \frac{h_t}{D_A \cdot \lambda}$$

[Open Calculator !\[\]\(e2376d476d06eb31946dc01a69a4403a_img.jpg\)](#)

$$\text{ex } 0.448^\circ = 4 \cdot \pi \cdot 70\text{m} \cdot \frac{32\text{m}}{40000\text{m} \cdot 90\text{m}}$$

12) Propagation Distance

$$\text{fx } P_d = 2 \cdot h \cdot \sqrt{\left(\frac{F_{\text{muf}}^2}{f_c^2} \right) - 1}$$

[Open Calculator !\[\]\(0b5e7e25e8775f7e7e80906ada4f0021_img.jpg\)](#)

$$\text{ex } 21714\text{m} = 2 \cdot 1169.985\text{m} \cdot \sqrt{\left(\frac{(420\text{Hz})^2}{(45\text{Hz})^2} \right) - 1}$$

13) Refractive Index of Ionosphere

$$\text{fx } \eta_r = \sqrt{1 - \left(\frac{81 \cdot N_{\text{max}}}{f_o^2} \right)}$$

[Open Calculator !\[\]\(bd3b31712ad9bab5a241210fa6925cdd_img.jpg\)](#)

$$\text{ex } 0.905539 = \sqrt{1 - \left(\frac{81 \cdot 2\text{e}10/\text{cm}^3}{(3\text{e}9\text{Hz})^2} \right)}$$



14) Skin Depth or Depth of Penetration

$$\text{fx } \delta = \frac{1}{\sigma} \cdot \sqrt{\pi \cdot \mu_r \cdot [\text{Permeability-vacuum}] \cdot f}$$

Open Calculator 

ex

$$0.006479\text{m} = \frac{1}{0.96\text{mho/m}} \cdot \sqrt{\pi \cdot 0.98\text{H/m} \cdot [\text{Permeability-vacuum}] \cdot 10\text{Hz}}$$

15) Skip Distance

$$\text{fx } P_d = 2 \cdot h_{\text{ref}} \cdot \sqrt{\left(\frac{F_{\text{muf}}}{f_c}\right)^2 - 1}$$

Open Calculator 

$$\text{ex } 21714.28\text{m} = 2 \cdot 1170\text{m} \cdot \sqrt{\left(\frac{420\text{Hz}}{45\text{Hz}}\right)^2 - 1}$$

16) Wavelength of Plane

$$\text{fx } \lambda = \lambda_n \cdot \cos(\theta)$$

Open Calculator 

$$\text{ex } 90.02334\text{m} = 103.95\text{m} \cdot \cos(30^\circ)$$



Variables Used

- **b** Antenna Beamwidth (Degree)
- **d** Antenna Diameter (Meter)
- **D_A** Antenna Distance (Meter)
- **E** Field Strength (Volt per Meter)
- **E₀** Electric Field (Volt per Meter)
- **f** Frequency of Conductor Loop (Hertz)
- **f_C** Critical Frequency (Hertz)
- **F_C** Critical Frequency of Ionosphere (Hertz)
- **F_{muf}** Maximum Usable Frequency (Hertz)
- **f_O** Operating Frequency (Hertz)
- **h** Ionospheric Layer Height (Meter)
- **h_r** Height of Receiving Antenna (Meter)
- **h_{ref}** Reflection Height (Meter)
- **h_t** Height of Transmitting Antenna (Meter)
- **LOS** Line of Sight (Meter)
- **N_{max}** Electron Density (1 per Cubic Centimeter)
- **P_d** Skip Distance (Meter)
- **δ** Skin Depth (Meter)
- **η_r** Refractive Index
- **θ** Theta (Degree)
- **θ_i** Angle of Incidence (Degree)
- **λ** Wavelength (Meter)
- **λ_n** Normal of Reflecting Plane (Meter)



- λ_p Parallel of Reflecting (Meter)
- μ_r Relative Permeability (Henry per Meter)
- σ Conductivity of Antenna (Mho per Meter)
- Φ Phase Difference (Degree)



Constants, Functions, Measurements used

- **Constant:** **pi**, 3.14159265358979323846264338327950288
Archimedes' constant
- **Constant:** **[Permeability-vacuum]**, $4 * \text{Pi} * 1\text{E-}7$ Henry / Meter
Permeability of vacuum
- **Function:** **cos**, cos(Angle)
Trigonometric cosine function
- **Function:** **sin**, sin(Angle)
Trigonometric sine function
- **Function:** **sqrt**, sqrt(Number)
Square root function
- **Measurement:** **Length** in Meter (m)
Length Unit Conversion 
- **Measurement:** **Angle** in Degree (°)
Angle Unit Conversion 
- **Measurement:** **Frequency** in Hertz (Hz)
Frequency Unit Conversion 
- **Measurement:** **Wavelength** in Meter (m)
Wavelength Unit Conversion 
- **Measurement:** **Electric Field Strength** in Volt per Meter (V/m)
Electric Field Strength Unit Conversion 
- **Measurement:** **Electric Conductivity** in Mho per Meter (mho/m)
Electric Conductivity Unit Conversion 
- **Measurement:** **Magnetic Permeability** in Henry per Meter (H/m)
Magnetic Permeability Unit Conversion 
- **Measurement:** **Number Density** in 1 per Cubic Centimeter (1/cm³)
Number Density Unit Conversion 



Check other formula lists

- [Antenna Theory Parameters Formulas](#) 
- [Special Antennas Formulas](#) 
- [Wave Propagation Formulas](#) 

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