Campi Elettromagnetici

Corso di Laurea in Ingegneria Informatica, Biomedica e delle Telecomunicazioni

a.a. 2023-2024 - Laurea “Triennale” – Secondo semestre - Secondo anno

Università degli Studi di Napoli “Parthenope”

Stefano Perna

Equazioni di Maxwell

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

		Unità di misura
$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$:	Campo elettrico	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$:	Induzione elettrica	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$:	Campo magnetico	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$:	Induzione magnetica	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$:	Densità di corrente	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$:	Densità di carica	Coulomb/m^3

Color legend

New formulas, important considerations, important formulas, important concepts

Very important for the discussion

Memo

Mathematical tools to be exploited

Mathematics

Maxwell equations

Differential form

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$$\nabla \cdot \vec{\mathbf{j}}(\vec{\mathbf{r}},t) + \frac{\partial \rho(\vec{\mathbf{r}},t)}{\partial t} = 0$$

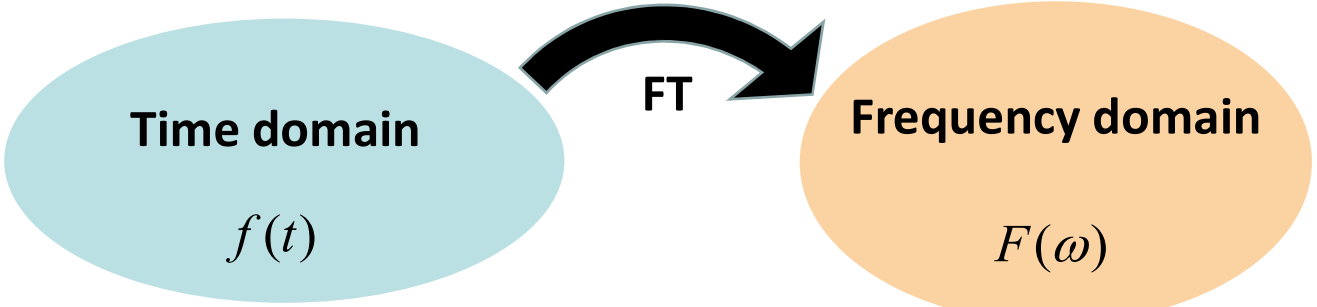
Integral form

$$\begin{cases} \oint_C dc\, \vec{\mathbf{e}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{c}} = -\dfrac{d}{dt} \iint_S dS\, \vec{\mathbf{b}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{n}} \\ \oint_C dc\, \vec{\mathbf{h}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{c}} = \dfrac{d}{dt} \iint_S dS\, \vec{\mathbf{d}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{n}} + i(t) \\ \oiint_S dS\, \vec{\mathbf{d}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{n}} = q(t) \\ \oiint_S dS\, \vec{\mathbf{b}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{n}} = 0 \end{cases}$$

$$\oiint_S dS\, \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \cdot \hat{\mathbf{n}} + \frac{dq(t)}{dt} = 0$$

Maxwell equations: Time domain, Frequency domain, Phasors

Frequency domain



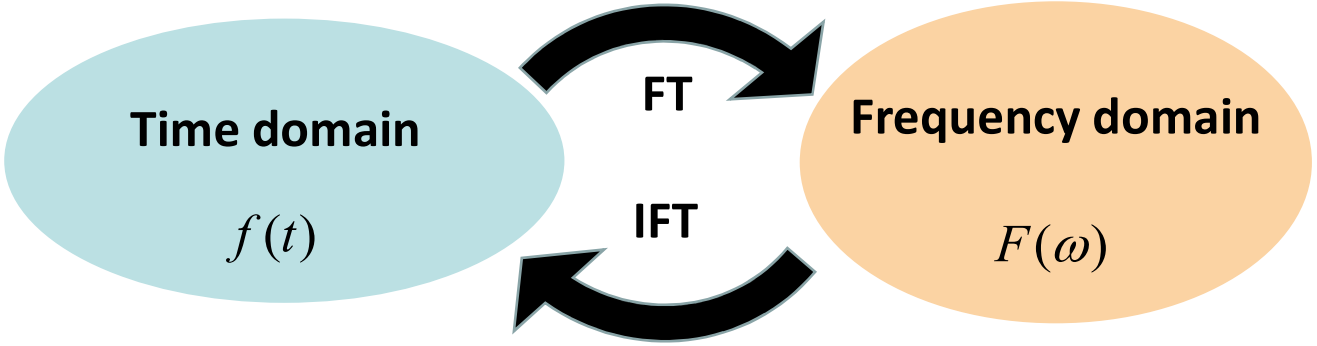
$$F(\omega)=\int_{-\infty}^{+\infty} f(t)e^{-j\omega t}dt$$

Fourier Transform (FT)

1) How to jump back from the Frequency domain to the Time domain

2) Time domain derivative and Fourier Transform

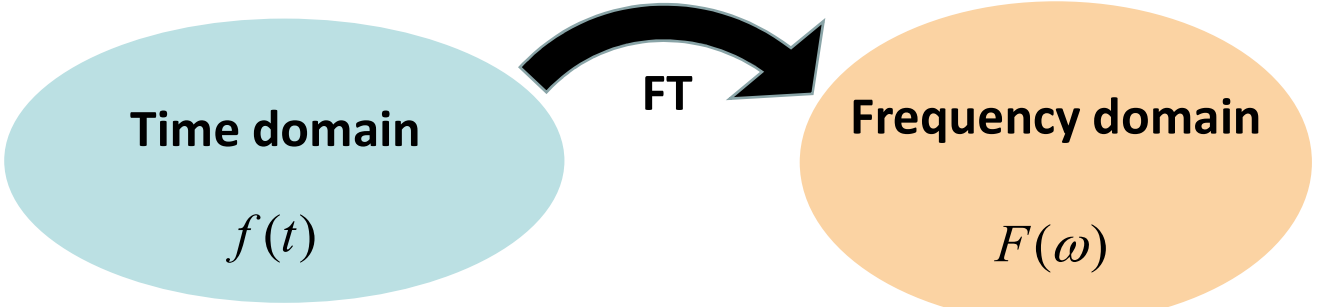
Frequency domain



$$f(t) \longrightarrow \boxed{\text{FT}} \longrightarrow F(\omega) = \int_{-\infty}^{+\infty} f(t) e^{-j\omega t} dt$$

$$F(\omega) \longrightarrow \boxed{\text{IFT}} \longrightarrow f(t) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} F(\omega) e^{j\omega t} d\omega$$

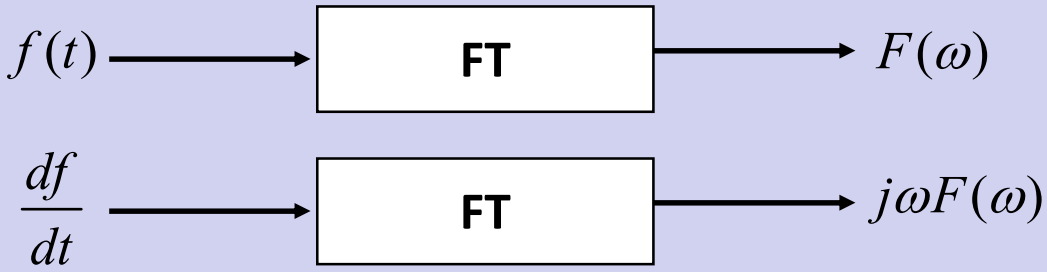
Frequency domain



$$F(\omega)=\int_{-\infty}^{+\infty} f(t)e^{-j\omega t}dt$$

Fourier Transform (FT)

2) Time-domain derivative and Fourier Transform



Frequency domain

- **Fourier Transform and functions of *n* variables**
- **Fourier Transform and vector functions**
- **Fourier Transform and vector functions of *n* variables**

1) How to jump back from the Frequency domain to the Time domain

2) Time domain derivative and Fourier Transform

Fourier Transform and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

$t \rightarrow \omega$

Frequency domain

$$\vec{\mathbf{F}}(\omega,x,y,z) = F_x(\omega,x,y,z)\hat{i}_x + F_y(\omega,x,y,z)\hat{i}_y + F_z(\omega,x,y,z)\hat{i}_z$$

$f_x(t,x,y,z)$ → **1D-FT** → $F_x(\omega,x,y,z) = \int_{-\infty}^{+\infty} f_x(t,x,y,z)\,e^{-j\omega t}\,dt$

$f_y(t,x,y,z)$ → **1D-FT** → $F_y(\omega,x,y,z) = \int_{-\infty}^{+\infty} f_y(t,x,y,z)\,e^{-j\omega t}\,dt$

$f_z(t,x,y,z)$ → **1D-FT** → $F_z(\omega,x,y,z) = \int_{-\infty}^{+\infty} f_z(t,x,y,z)\,e^{-j\omega t}\,dt$

Fourier Transform and vector functions of *n* variables

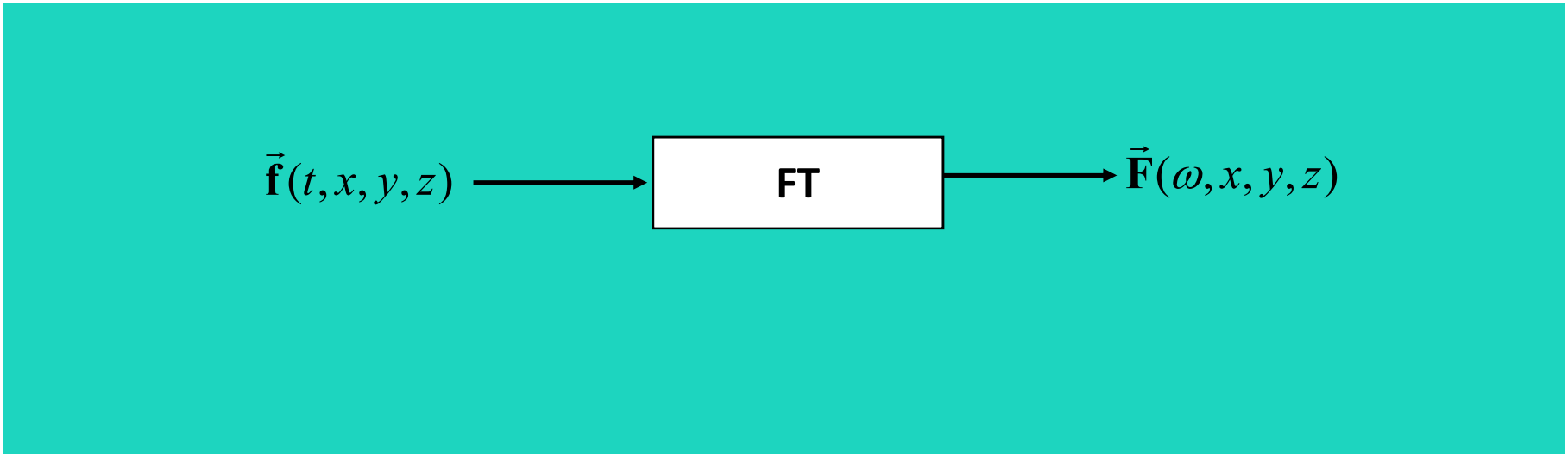
Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

$t \rightarrow \omega$

Frequency domain

$$\vec{\mathbf{F}}(\omega,x,y,z) = F_x(\omega,x,y,z)\hat{i}_x + F_y(\omega,x,y,z)\hat{i}_y + F_z(\omega,x,y,z)\hat{i}_z$$



Fourier Transform and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

$\omega \to t$

Frequency domain

$$\vec{\mathbf{F}}(\omega,x,y,z) = F_x(\omega,x,y,z)\hat{i}_x + F_y(\omega,x,y,z)\hat{i}_y + F_z(\omega,x,y,z)\hat{i}_z$$

1) How to jump back from the Spectral domain to the Time domain

$F_x(\omega,x,y,z)$ → **1D-IFT** → $f_x(t,x,y,z) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} F_x(\omega,x,y,z)e^{j\omega t}d\omega$

$F_y(\omega,x,y,z)$ → **1D-IFT** → $f_y(t,x,y,z) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} F_y(\omega,x,y,z)e^{j\omega t}d\omega$

$F_z(\omega,x,y,z)$ → **1D-IFT** → $f_z(t,x,y,z) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} F_z(\omega,x,y,z)e^{j\omega t}d\omega$

Fourier Transform and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

$t \rightarrow \omega$

Frequency domain

$$\vec{\mathbf{F}}(\omega,x,y,z) = F_x(\omega,x,y,z)\hat{i}_x + F_y(\omega,x,y,z)\hat{i}_y + F_z(\omega,x,y,z)\hat{i}_z$$

2) Time domain derivative and Fourier Transform $t \rightarrow \omega$

$\vec{\mathbf{f}}(t,x,y,z)$ → **FT** → $\vec{\mathbf{F}}(\omega,x,y,z)$

$\frac{\partial \vec{\mathbf{f}}}{\partial t}$ → **FT** → $j\omega\vec{\mathbf{F}}(\omega,x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → **FT** → $\nabla \cdot \vec{\mathbf{F}}(\omega,x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → **FT** → $\nabla \times \vec{\mathbf{F}}(\omega,x,y,z)$

Fourier Transform and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(x,y,z,t) = f_x(x,y,z,t)\hat{i}_x + f_y(x,y,z,t)\hat{i}_y + f_z(x,y,z,t)\,\hat{i}_z$$

$t \rightarrow \omega$

Frequency domain

$$\vec{\mathbf{F}}(x,y,z,\omega) = F_x(x,y,z,\omega)\hat{i}_x + F_y(x,y,z,\omega)\hat{i}_y + F_z(x,y,z,\omega)\hat{i}_z$$

2) Time domain derivative and Fourier Transform

$t \rightarrow \omega$

$\vec{\mathbf{f}}(x,y,z,t)$ → **FT** → $\vec{\mathbf{F}}(x,y,z,\omega)$

$\frac{\partial \vec{\mathbf{f}}}{\partial t}$ → **FT** → $j\omega\vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}}$ → **FT** → $\nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}}$ → **FT** → $\nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \\ \\ \\ \\ \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

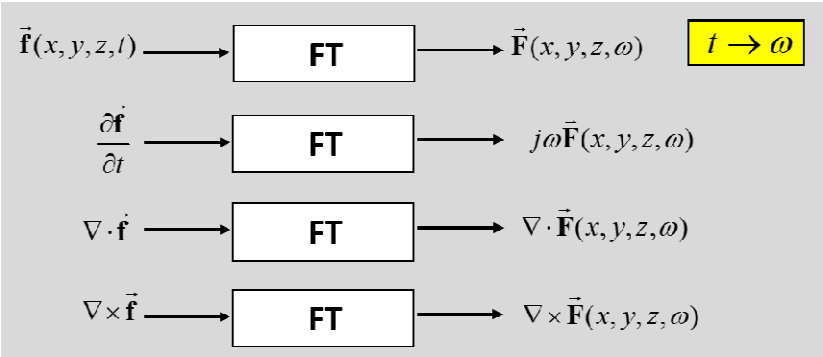
Time domain

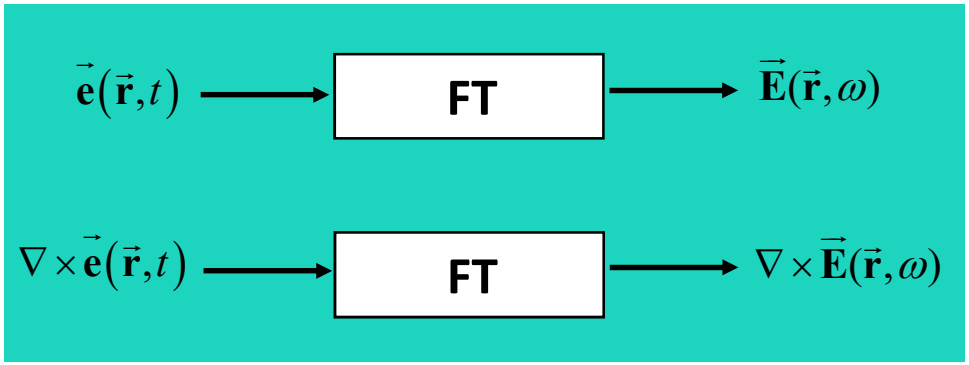
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \end{cases}$$





Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega\vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$

$\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) \\ \\ \\ \\ \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega\vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

$\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \rightarrow$ FT $\rightarrow j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

$\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \to \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{h}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{h}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$

$\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{h}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$

$\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$t \rightarrow \omega$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

$\dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \to \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

$\dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{j}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \to \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{j}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \to \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

$\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

$\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

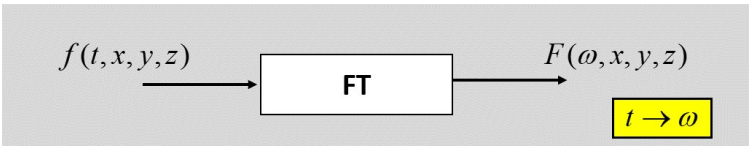
Time domain

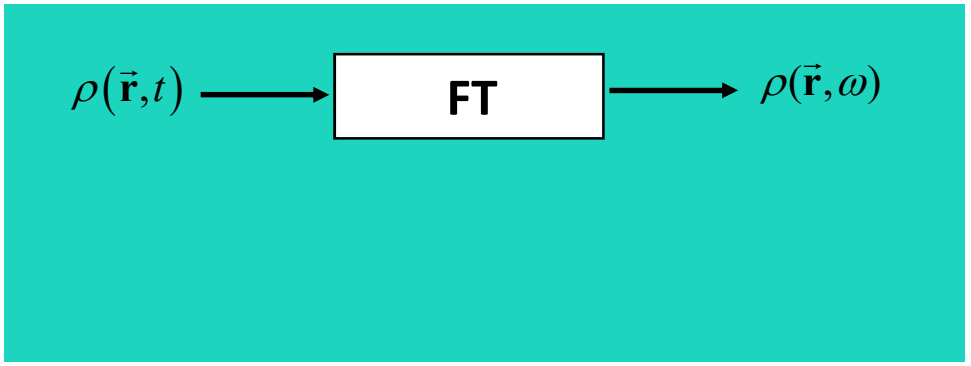
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) \end{cases}$$





Maxwell equations
Time domain & Frequency domain

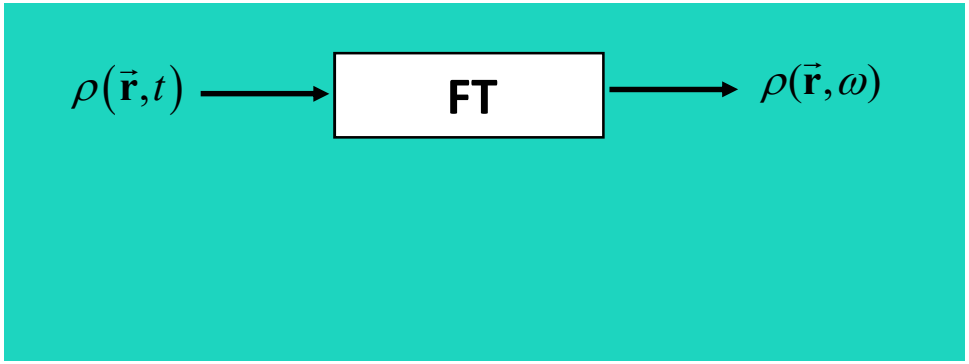
Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \end{cases}$$



Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla\times\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \to \omega$

$\dfrac{\partial\vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega\vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla\cdot\vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla\cdot\vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla\times\vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla\times\vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

$\nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla\cdot\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \rightarrow$ FT $\rightarrow \vec{\mathbf{F}}(x,y,z,\omega)$ $\quad t \rightarrow \omega$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \rightarrow$ FT $\rightarrow j\omega \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \cdot \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z,\omega)$

$\nabla \times \vec{\mathbf{f}} \rightarrow$ FT $\rightarrow \nabla \times \vec{\mathbf{F}}(x,y,z,\omega)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

$\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) \rightarrow$ FT $\rightarrow \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla\times\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m	$\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2	$\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m	$\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2	$\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2	$\vec{\mathbf{J}}(\vec{\mathbf{r}},\omega)$
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3	$\rho(\vec{\mathbf{r}},\omega)$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

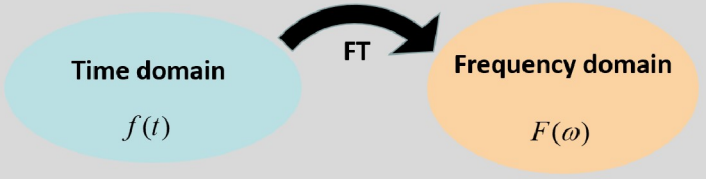
Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

$\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$

..memo



Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

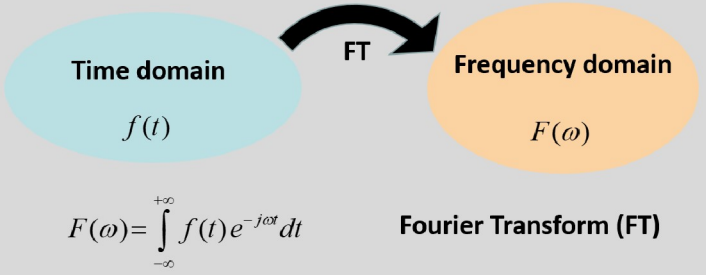
Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

$\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$ (Volt x s) /m

..memo



Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \rightarrow \omega$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m	$\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega)$	(Volt x s) /m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2	$\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega)$	(Coulomb x s)/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m	$\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega)$	(Ampere x s)/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2	$\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega)$	(Weber x s)/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2	$\vec{\mathbf{J}}(\vec{\mathbf{r}},\omega)$	(Ampere x s)/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3	$\rho(\vec{\mathbf{r}},\omega)$	(Coulomb x s)/m^3

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla\times\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$$\frac{\partial\rho(\vec{\mathbf{r}},t)}{\partial t} + \nabla\cdot\vec{\mathbf{j}}(\vec{\mathbf{r}},t) = 0$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla\times\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

Maxwell equations
Time domain & Frequency domain

Time domain

$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$$\frac{\partial\rho(\vec{\mathbf{r}},t)}{\partial t} + \nabla\cdot\vec{\mathbf{j}}(\vec{\mathbf{r}},t) = 0$$

$t \to \omega$

Frequency domain

$$\begin{cases} \nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla\times\vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla\cdot\vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$$j\omega\rho(\vec{\mathbf{r}},\omega) + \nabla\cdot\vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) = 0$$

Phasors

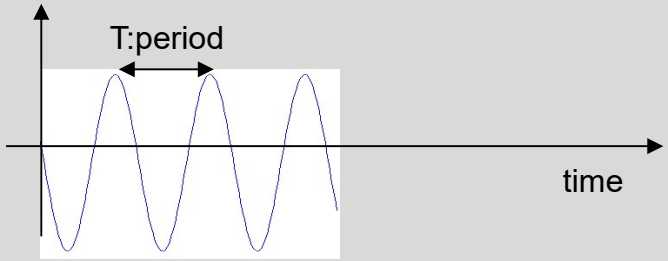
Time domain

$$f(t) = A\cos\left(\omega_0 t + \alpha\right)$$

Phasor domain

$$F = Ae^{j\alpha}$$

Signals usually adopted in ICT applications

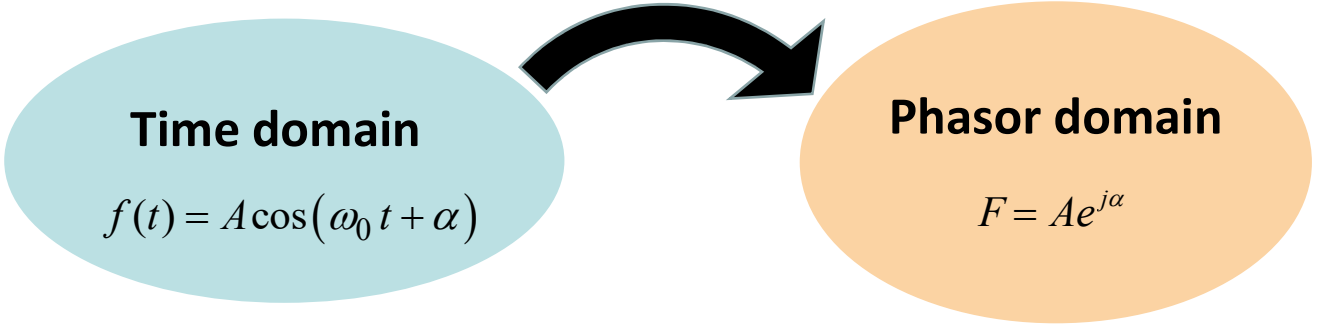


$$f(t) = A\cos\left(2\pi f_0 t + \alpha\right)$$

$$f_0 : frequency = \frac{1}{T}$$

$$\omega_0 : angular\ frequency = 2\pi f_0$$

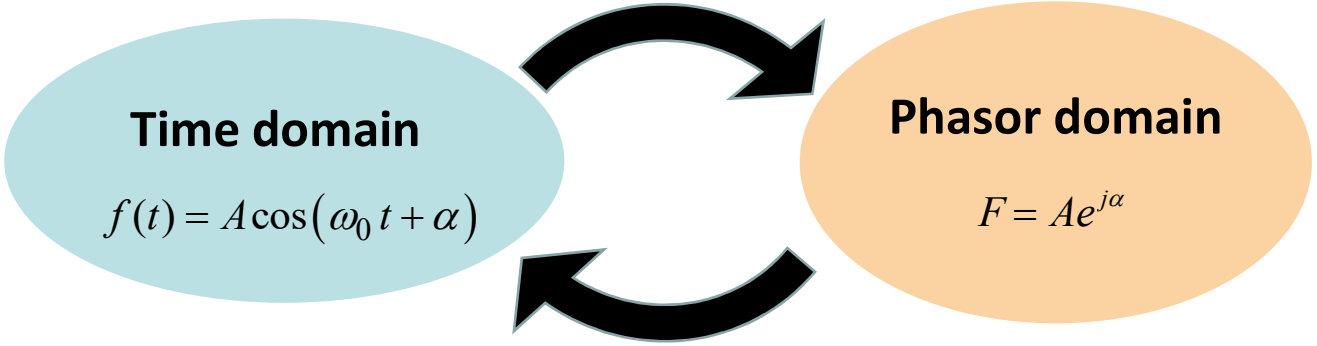
Phasors



1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

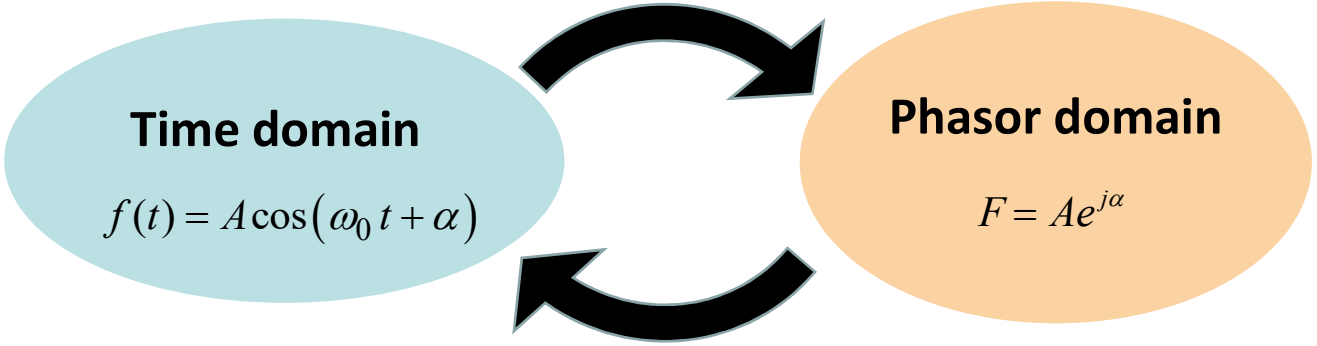
Phasors



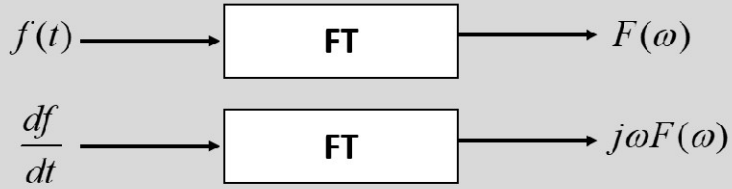
$f(t) = A\cos(\omega_0 t + \alpha)$ → **T-to-P** → $F = Ae^{j\alpha}$

$F = Ae^{j\alpha}$ → **P-to-T** → $f(t) = \mathrm{Re}\{Fe^{j\omega_0 t}\} = A\cos(\omega_0 t + \alpha)$

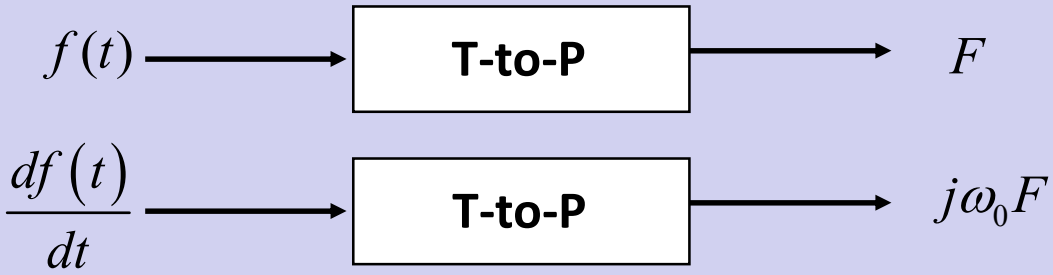
Phasors



... memo ...



2) Time domain derivative and Phasors



ω_0 now is fixed!

Phasors

- **Phasors and functions of *n* variables**
- **Phasors and vector functions**
- **Phasors and vector functions of *n* variables**

1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

Phasors

- Phasors and functions of n variables
- Phasors and vector functions
- **Phasors and vector functions of *n* variables**

1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

$$f_x(t,x,y,z) = A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right)$$

$$f_y(t,x,y,z) = A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right)$$

$$f_z(t,x,y,z) = A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right)$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$$f_x(t,x,y,z) = A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right)$$

$$f_y(t,x,y,z) = A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right)$$

$$f_z(t,x,y,z) = A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right)$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

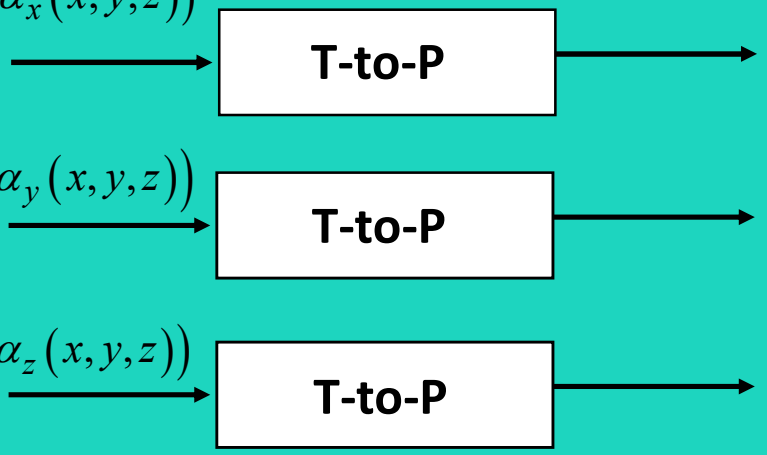
Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$$f_x(t,x,y,z) = A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right)$$

$$f_y(t,x,y,z) = A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right)$$

$$f_z(t,x,y,z) = A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right)$$



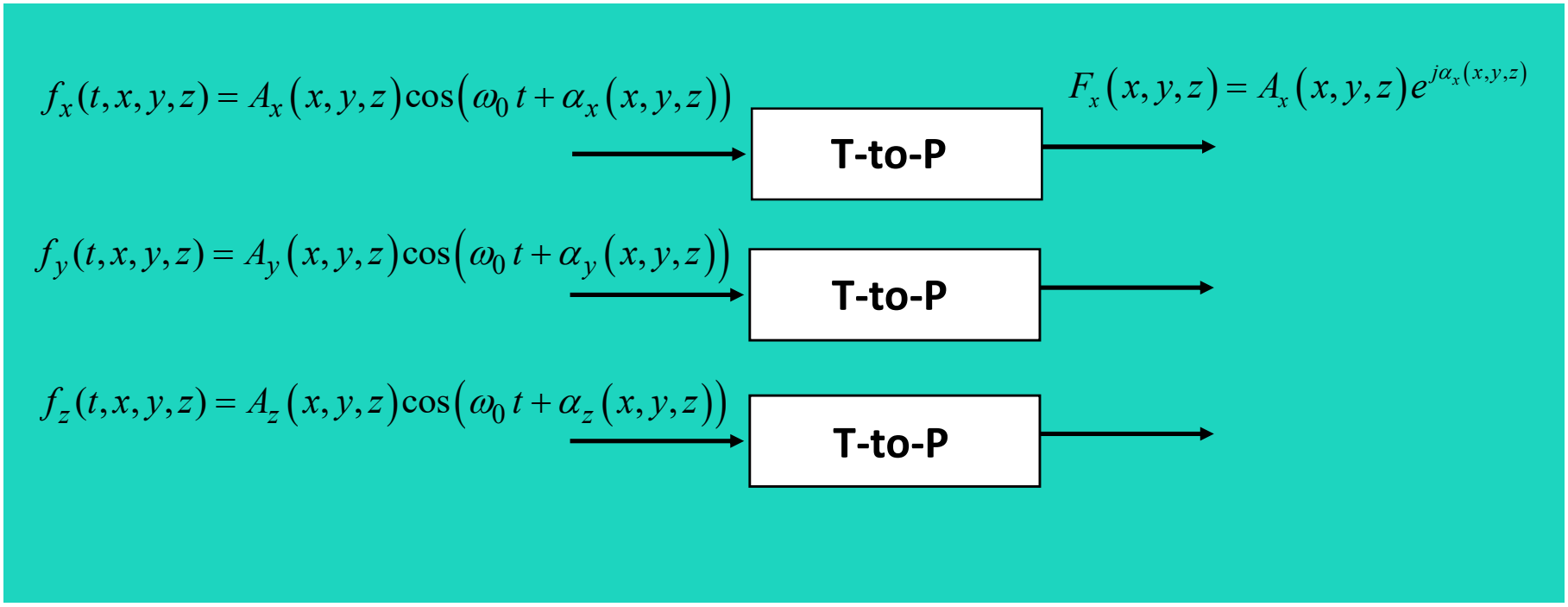
Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$



Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$$f_x(t,x,y,z) = A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right) \rightarrow \boxed{\text{T-to-P}} \rightarrow F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)}$$

$$f_y(t,x,y,z) = A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right) \rightarrow \boxed{\text{T-to-P}} \rightarrow F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)}$$

$$f_z(t,x,y,z) = A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right) \rightarrow \boxed{\text{T-to-P}} \rightarrow F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$$\vec{\mathbf{f}}(t,x,y,z) \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \vec{\mathbf{F}}(x,y,z)$$

$$\begin{aligned}\vec{\mathbf{f}}(t,x,y,z) &= f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\hat{i}_z = \\ &= A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right)\hat{i}_x + \\ &\quad A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right)\hat{i}_y + \\ &\quad A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right)\hat{i}_z\end{aligned}$$

$$\begin{aligned}\vec{\mathbf{F}}(x,y,z) &= F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z = \\ &= A_x(x,y,z)e^{j\alpha_x(x,y,z)}\hat{i}_x + A_y(x,y,z)e^{j\alpha_y(x,y,z)}\hat{i}_y + A_z(x,y,z)e^{j\alpha_z(x,y,z)}\hat{i}_z\end{aligned}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)}$ → **P-to-T** →

$F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)}$ → **P-to-T** →

$F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)}$ → **P-to-T** →

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)}$ → **P-to-T** → $f_x(t,x,y,z) = \mathrm{Re}\left\{F_x(x,y,z)e^{j\omega_0 t}\right\}$

$F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)}$ → **P-to-T**

$F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)}$ → **P-to-T**

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$$F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_x(t,x,y,z) = \text{Re}\left\{F_x(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_y(t,x,y,z) = \text{Re}\left\{F_y(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_z(t,x,y,z) = \text{Re}\left\{F_z(x,y,z)e^{j\omega_0 t}\right\}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$$\vec{\mathbf{F}}(x,y,z) \longrightarrow \boxed{\text{P-to-T}} \longrightarrow \vec{\mathbf{f}}(t,x,y,z) = \mathrm{Re}\left\{\vec{\mathbf{F}}(x,y,z)e^{j\omega_0 t}\right\}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\frac{\partial \vec{\mathbf{f}}}{\partial t}$ → **T-to-P** →

$$\frac{\partial \vec{\mathbf{f}}(t,\vec{\mathbf{r}})}{\partial t} = \frac{\partial f_x}{\partial t}\hat{i}_x + \frac{\partial f_y}{\partial t}\hat{i}_y + \frac{\partial f_z}{\partial t}\hat{i}_z$$

$\frac{\partial f_x(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_x(x,y,z)$

$\frac{\partial f_y(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_y(x,y,z)$

$\frac{\partial f_z(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_z(x,y,z)$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → **T-to-P** → $j\omega_0 \vec{\mathbf{F}}(x,y,z) = j\omega_0 F_x(x,y,z)\hat{i}_x + j\omega_0 F_y(x,y,z)\hat{i}_y + j\omega_0 F_z(x,y,z)\hat{i}_z$

$$\frac{\partial \vec{\mathbf{f}}(t,\vec{\mathbf{r}})}{\partial t} = \frac{\partial f_x}{\partial t}\hat{i}_x + \frac{\partial f_y}{\partial t}\hat{i}_y + \frac{\partial f_z}{\partial t}\hat{i}_z$$

$\dfrac{\partial f_x(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_x(x,y,z)$

$\dfrac{\partial f_y(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_y(x,y,z)$

$\dfrac{\partial f_z(t)}{\partial t}$ → **T-to-P** → $j\omega_0 F_z(x,y,z)$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\nabla\cdot\vec{\mathbf{f}}$ → **T-to-P** → $\nabla\cdot\vec{\mathbf{F}}(x,y,z)$

$$\nabla\cdot\vec{\mathbf{f}}(t,\vec{\mathbf{r}}) = \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + \frac{\partial f_z}{\partial z}$$

$\frac{\partial f_x}{\partial x}$ → **T-to-P** → $\frac{\partial F_x(x,y,z)}{\partial x}$

$\frac{\partial f_y}{\partial y}$ → **T-to-P** → $\frac{\partial F_y(x,y,z)}{\partial y}$

$\frac{\partial f_z}{\partial z}$ → **T-to-P** → $\frac{\partial F_z(x,y,z)}{\partial z}$

Phasors and vector functions of *n* variables

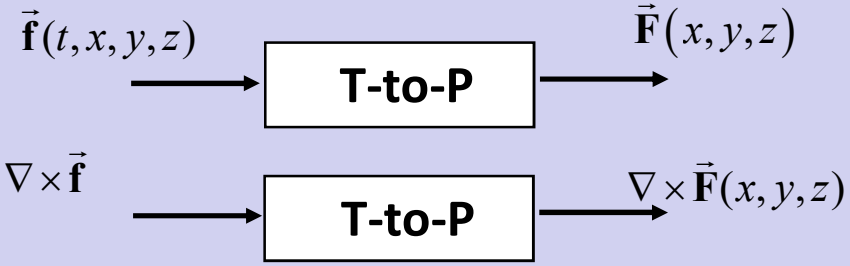
Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors



$$\nabla\times\vec{\mathbf{f}}(t,\vec{\mathbf{r}}) = \left(\frac{\partial f_z}{\partial y} - \frac{\partial f_y}{\partial z}\right)\hat{i}_x + \left(\frac{\partial f_x}{\partial z} - \frac{\partial f_z}{\partial x}\right)\hat{i}_y + \left(\frac{\partial f_y}{\partial x} - \frac{\partial f_x}{\partial y}\right)\hat{i}_z$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\frac{\partial \vec{\mathbf{f}}}{\partial t}$ → **T-to-P** → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → **T-to-P** → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → **T-to-P** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(x,y,z,t) = f_x(x,y,z,t)\hat{i}_x + f_y(x,y,z,t)\hat{i}_y + f_z(x,y,z,t)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \vec{\mathbf{F}}(x,y,z)$$

$$\frac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$$

$$\nabla \cdot \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$$

$$\nabla \times \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$$