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Lampiran 1: Persamaan Maxwell

Persamaan Maxwell yang digunakan dalam metode magnetotellurik:

$$\mathbf{\nabla} \text{ x } \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \quad (1.1a)$$

$$\mathbf{\nabla} \text{ x } \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t} \quad (1.1b)$$

$$\mathbf{\nabla} \cdot \mathbf{D} = q \quad (1.1c)$$

$$\mathbf{\nabla} \cdot \mathbf{B} = 0 \quad (1.1d)$$

Hubungan antara intensitas medan dengan fluks yang terjadi pada medium dinyatakan oleh persamaan berikut:

$$\mathbf{B} = \mu \mathbf{H} \quad (1.2a)$$

$$\mathbf{D} = \varepsilon \mathbf{E} \quad (1.2b)$$

$$\mathbf{J} = \sigma \mathbf{E} = \frac{\mathbf{E}}{\rho} \quad (1.2c)$$

Maka persamaan Maxwell dapat dituliskan kembali sebagai berikut:

$$\mathbf{\nabla} \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \quad (1.3a)$$

$$\mathbf{\nabla} \times \mathbf{H} = \sigma \mathbf{E} + \varepsilon \frac{\partial \mathbf{E}}{\partial t} \quad (1.3b)$$

$$\mathbf{\nabla} \cdot \mathbf{E} = 0 \quad (1.3c)$$

$$\mathbf{\nabla} \cdot \mathbf{H} = 0 \quad (1.3d)$$

Dengan menggunakan identitas vektor ($\nabla \times (\mathbf{\nabla} \times \boldsymbol{x}) = \nabla(\mathbf{\nabla} \cdot \boldsymbol{x}) - \mathbf{\nabla}^2 \boldsymbol{x}$), dimana **x** adalah **E** dan **H**:

$$\nabla \times (\mathbf{\nabla} \times \mathbf{E}) = \nabla(\mathbf{\nabla} \cdot \mathbf{E}) - \mathbf{\nabla}^2 \mathbf{E}) \quad (1.4a)$$

$$\nabla \times (\mathbf{\nabla} \times \mathbf{H}) = \nabla(\mathbf{\nabla} \cdot \mathbf{H}) - \mathbf{\nabla}^2 \mathbf{H}) \quad (1.4b)$$

Maka persamaan (2.4a) dan (2.4b) menjadi:

$$\nabla \times (\mathbf{\nabla} \times \mathbf{E}) = -\mathbf{\nabla}^2 \mathbf{E} \quad (1.5a)$$

$$\nabla \times (\mathbf{\nabla} \times \mathbf{H}) = -\mathbf{\nabla}^2 \mathbf{H} \quad (1.5b)$$

Maka dapat dituliskan sebagai berikut:

$$\nabla \times (\mathbf{\nabla} \times \mathbf{E}) = -\mu\sigma \frac{\partial \mathbf{E}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} \quad (1.6a)$$

$$\nabla \times (\boldsymbol{\nabla} \times \mathbf{H}) = -\mu\sigma \frac{\partial \mathbf{H}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} \tag{1.6b}$$

Dengan mensubtitusikan persamaan (1.5) ke persamaan (1.6) maka dapat dituliskan sebagai berikut:

$$\nabla \times (\boldsymbol{\nabla} \times \mathbf{E}) + \mu\sigma \frac{\partial \mathbf{E}}{\partial t} + \mu\varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0 \tag{1.7a}$$

$$\nabla \times (\boldsymbol{\nabla} \times \mathbf{H}) + \mu\sigma \frac{\partial \mathbf{H}}{\partial t} + \mu\varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} = 0 \tag{1.7b}$$

Maka kita dapatkan persamaan gelombang (persamaan Helmoltz) untuk medan listrik dan medan magnet sebagai berikut:

$$\nabla^2 \mathbf{E} - \mu\sigma \frac{\partial \mathbf{E}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0 \tag{1.8a}$$

$$\nabla^2 \mathbf{H} - \mu\sigma \frac{\partial \mathbf{H}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} = 0 \tag{1.8b}$$

Dalam pendekatan metode magnetotellurik biasa digunakan medan elektromagnetik yang bervariasi secara sinusoidal terhadap waktu. Secara matematis dapat dituliskan sebagai berikut:

$$\mathbf{E} = \mathbf{E}_0 e^{i\omega t - kz} \tag{1.9a}$$

$$\mathbf{H} = \mathbf{H}_0 e^{i\omega t - kz} \tag{1.9b}$$

Dengan mensubtitusikan persamaan (1.9) ke dalam persamaan (1.8) maka diperoleh:

$$\nabla^2 \mathbf{E} - \mu\sigma \frac{\partial \mathbf{E}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0$$

$$\nabla^2 \mathbf{E} - \mu\sigma \frac{\partial \mathbf{E}_0 e^{i\omega t - kz}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{E}_0 e^{i\omega t - kz}}{\partial t^2} = 0$$

$$\nabla^2 \mathbf{E} - i\omega\mu\sigma \mathbf{E}_0 e^{i\omega t - kz} - i\omega\mu\varepsilon \frac{\partial \mathbf{E}_0 e^{i\omega t - kz}}{\partial t} = 0$$

$$\nabla^2 \mathbf{E} - i\omega\mu\sigma(\mathbf{E}) - i^2\omega^2\mu\varepsilon(\mathbf{E}) = 0 \tag{1.10}$$

Dan,

$$\nabla^2 \mathbf{H} - \mu\sigma \frac{\partial \mathbf{H}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} = 0$$

$$\nabla^2 \mathbf{H} - \mu\sigma \frac{\partial \mathbf{H}_0 e^{i\omega t - kz}}{\partial t} - \mu\varepsilon \frac{\partial^2 \mathbf{H}_0 e^{i\omega t - kz}}{\partial t^2} = 0$$

$$\nabla^2\mathbf{H} - \mathrm{i}\omega\mu\sigma\mathbf{H}_0 e^{\mathrm{i}\omega t - kz} - \mathrm{i}\omega\mu\varepsilon\frac{\partial \mathbf{H}_0 e^{\mathrm{i}\omega t - kz}}{\partial t} = 0$$

$$\nabla^2\mathbf{H} - \mathrm{i}\omega\mu\sigma(\mathbf{H}) - \mathrm{i}^2\omega^2\mu\varepsilon(\mathbf{H}) = 0 \qquad (1.11)$$

Karena, $i^2 = -1$ atau $i = \sqrt{-1}$, maka:

$$\nabla^2\mathbf{E} - \mathrm{i}\omega\mu\sigma(\mathbf{E}) + \omega^2\mu\varepsilon(\mathbf{E}) = 0 \qquad (1.12a)$$

$$\nabla^2\mathbf{H} - \mathrm{i}\omega\mu\sigma(\mathbf{H}) + \omega^2\mu\varepsilon(\mathbf{H}) = 0 \qquad (1.12b)$$

Atau,

$$\nabla^2\mathbf{E} = (\mathrm{i}\omega\mu\sigma - \omega^2\mu\varepsilon)\mathbf{E} \qquad (1.13a)$$

$$\nabla^2\mathbf{H} = (\mathrm{i}\omega\mu\sigma - \omega^2\mu\varepsilon)\mathbf{H} \qquad (1.13b)$$

Perambatan dalam medium bumi (material bumi memiliki nilai konduktifitas $10^{-3} S/m \leq \sigma \leq 10^3 S/m$ dan nilai permitivitas ε dianggap sama dengan ε_0) dan gelombang yang merambat memiliki frekuensi rendah ($f < 10\ kHz$) maka $\sigma \gg \varepsilon\omega$, sehingga persamaan (1.13) menjadi:

$$\nabla^2\mathbf{E} = \mathrm{i}\omega\mu\sigma\mathbf{E} \qquad (1.14a)$$

$$\nabla^2\mathbf{H} = \mathrm{i}\omega\mu\sigma\mathbf{H} \qquad (1.14b)$$

Atau:

$$k^2\mathbf{E} - \mathrm{i}\omega\mu\sigma\mathbf{E} = 0 \qquad (1.15a)$$

$$k^2\mathbf{H} - \mathrm{i}\omega\mu\sigma\mathbf{H} = 0 \qquad (1.15b)$$

Dimana k merupakan bilangan gelombang.

Lampiran 2: Bilangan gelombang (k)

Nilai k diperoleh dari:

$$\nabla^2\mathbf{E} = \mu\sigma\frac{\partial\mathbf{E}}{\partial t} + \mu\varepsilon\frac{\partial^2\mathbf{E}}{\partial t^2}$$

$$\frac{\partial^2(\mathbf{E}_0 e^{ikz} e^{i\omega t})}{\partial z^2} = \mu\sigma\frac{\partial(\mathbf{E}_0 e^{ikz} e^{i\omega t})}{\partial t} + \mu\varepsilon\frac{\partial^2(\mathbf{E}_0 e^{ikz} e^{i\omega t})}{\partial t^2}$$

$$-ik\frac{\partial(\mathbf{E}_0 e^{ikz} e^{i\omega t})}{\partial z} = \mu\sigma i\omega\mathbf{E}_0 e^{ikz} e^{i\omega t} + i\omega\mu\varepsilon\frac{\partial(\mathbf{E}_0 e^{ikz} e^{i\omega t})}{\partial t}$$

$$k^2\mathbf{E}_0 e^{ikz} e^{i\omega t} = i\omega\mu\sigma\mathbf{E}_0 e^{ikz} e^{i\omega t} - \omega^2\mu\varepsilon\mathbf{E}_0 e^{ikz} e^{i\omega t}$$

$$k^2\mathbf{E} = i\omega\mu\sigma\mathbf{E} - \omega^2\mu\varepsilon\mathbf{E}$$

$$k^2\mathbf{E} = (i\omega\mu\sigma - \omega^2\mu\varepsilon)\mathbf{E}$$

$$k^2 = (i\omega\mu\sigma - \omega^2\mu\varepsilon)$$

Karena nilai $\varepsilon < \sigma$, maka:

$$k^2 = i\omega\mu\sigma$$

Atau:

$$k = \sqrt{i\omega\mu\sigma} \qquad (2.1)$$

Lampiran 3: Skin depth (δ)

$$k = \sqrt{\mathrm{i}\omega\mu\sigma}$$

$$k = \sqrt{\mathrm{i}}\sqrt{\omega\mu\sigma}$$

Diketahui:

$$\frac{1+i}{\sqrt{2}} = \sqrt{i}$$

$$\frac{(1+i)^2}{2} = i$$

$$\frac{1+2i+i^2}{2} = i$$

$$1 + i + i^2 = i$$

$$1 + i - 1 = i$$

$i = i$ (TERBUKTI)

Maka,

$$k = \frac{1+i}{\sqrt{2}}\sqrt{\omega\mu\sigma}$$

$$k = \sqrt{\frac{\omega\mu\sigma}{2}} + i\sqrt{\frac{\omega\mu\sigma}{2}}$$

$$k = \sqrt{\frac{\omega\mu\sigma}{2}} \qquad (3.1)$$

Sehingga,

$\delta = \frac{1}{Re(k)} = \sqrt{\frac{2}{\omega\mu\sigma}}$, dimana $\sigma = \frac{1}{\rho}$, maka:

$= \sqrt{\frac{2\rho}{\mu\omega}}$, dimana $\mu = 4\pi \text{ x } 10^{-7}$dan $\omega = 2\pi f = \frac{2\pi}{T}$

$$= \sqrt{\frac{2\rho}{(4\pi \text{ x } 10^{-7})(\frac{2\pi}{T})}}$$

$$= \sqrt{\frac{\rho T}{(4\pi^2 \text{ x } 10^{-7})}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{\rho T}{(10^{-1}.10^{-6})}}$$

$$= \frac{1}{2\pi}\sqrt{\rho T 10.10^6}$$

$$= \frac{1}{2\pi}10^3\sqrt{\rho T 10}$$

$$= \frac{1}{2\pi}3{,}16(10^3)\sqrt{\rho T}$$

$$= 503\sqrt{\frac{\rho}{f}}\,(\mathrm{m}) \qquad (3.2)$$

Lampiran 4: Impedansi

Tensor impedansi sebagai berikut:

$$Z = \frac{E}{H} \quad (4.1)$$

Berdasarkan arah induksi:

$$Z_{xy} = \frac{E_x}{H_y} = \sqrt{i\omega\mu\rho} \quad (4.2a)$$

$$Z_{yx} = -\frac{E_y}{H_x} = -\sqrt{i\omega\mu\rho} \quad (4.2b)$$

Untuk struktur yang bervariasi terhadap lateral, maka nilai impedansinya dalam bentuk linier:

$$E_x = Z_{xx}H_x + Z_{xy}H_y \quad (4.3a)$$

$$E_y = Z_{yx}H_x + Z_{yy}H_y \quad (4.3b)$$

Maka diperoleh tahanan jenis semu:

$$Z_i = \frac{E}{H} = \frac{i\omega\mu}{k}$$

$$Z_i = \frac{i\omega\mu}{\sqrt{i\omega\mu\sigma}}$$

$$\sqrt{i\omega\mu\sigma} = \left(\frac{i\omega\mu}{Z_i}\right)^2$$

$$i\omega\mu\sigma = \frac{i\omega\mu}{Z_i}$$

$$Z_i{}^2 = \frac{(i\omega\mu)(i\omega\mu)}{i\omega\mu\sigma}$$

$Z_i{}^2 = \frac{i\omega\mu}{\sigma}$, dimana $\sigma = \frac{1}{\rho}$, maka:

$$Z_i{}^2 = i\omega\mu\rho$$

$$\rho = \frac{Z_i{}^2}{i\omega\mu}$$

$$\rho = \frac{1}{i\omega\mu}\left|Z_i{}^2\right| \quad (4.4)$$

Dan untuk *phase*, sebagai berikut:

$$\emptyset = \tan^{-1}\left(\frac{ImZ_i}{ReZ_i}\right) \quad (4.5)$$

Lampiran 5: Polarization Mode

A. Mode *Transverse Electric* (TE)

Berdasarkan persamaan Maxwell (2.3b), solusi fungsi periodik sinusoidal $\mathbf{E} = \mathbf{E}_0 e^{i\omega t - kz}$, dimana $\hat{y} = \sigma + i\varepsilon\omega$, maka:

$$\nabla \times \mathbf{H} = \sigma\mathbf{E} + \varepsilon\frac{\partial \mathbf{E}}{\partial t}$$

$$\nabla \times \mathbf{H} = \sigma\mathbf{E} + \varepsilon\frac{\partial e^{i\omega t}}{\partial t}$$

$$\nabla \times \mathbf{H} = \sigma\mathbf{E} + \varepsilon i\omega e^{i\omega t}$$

$$\nabla \times \mathbf{H} = \sigma\mathbf{E} + \varepsilon i\omega\mathbf{E}$$

$$\nabla \times \mathbf{H} = \mathbf{E}\,(\sigma + \varepsilon i\omega)$$

$$\nabla \times \mathbf{H} = \hat{y}\mathbf{E} \tag{5.1}$$

Bumi bersifat konduktif, maka suku mengandung ε dapat diabaikan, sehingga $\hat{y} = \sigma$

$$\nabla \times \mathbf{H} = \hat{y}\mathbf{E}$$

$$\left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right) \times \left(\mathbf{H}_x\hat{\imath} + \mathbf{H}_y\hat{\jmath} + \mathbf{H}_z\hat{k}\right) = \hat{y}(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k})$$

$$\begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \mathbf{H}_x & \mathbf{H}_y & \mathbf{H}_z \end{vmatrix} \begin{vmatrix} \hat{\imath} & \hat{\jmath} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} \\ \mathbf{H}_x & \mathbf{H}_y \end{vmatrix}$$

$$\hat{\imath}\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right) + \hat{\jmath}\left(\frac{\partial \mathbf{H}_x}{\partial z} - \frac{\partial \mathbf{H}_z}{\partial x}\right) + \hat{k}\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k})$$

Karena medan listrik merambat secara vertikal dalam arah sumbu $x(\hat{\imath})$, maka komponen $y(\hat{\jmath})$ dan $z(\hat{k})$ bernilai nol menjadi:

$$= \hat{\imath}\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right) + \hat{\jmath}\left(\frac{\partial \mathbf{H}_x}{\partial z} - \frac{\partial \mathbf{H}_z}{\partial x}\right) + \hat{k}\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right)$$

$$= \hat{y}(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k})$$

$$= \hat{y}\mathbf{E}_x\hat{\imath} \tag{5.2}$$

Menjadi:

$$\hat{\imath}\left(\frac{\partial \boldsymbol{H}_z}{\partial y}-\frac{\partial \boldsymbol{H}_y}{\partial z}\right)=(\hat{y}\boldsymbol{E}_{\boldsymbol{x}}\hat{\imath})$$

$$\left(\frac{\partial \boldsymbol{H}_z}{\partial y}-\frac{\partial \boldsymbol{H}_y}{\partial z}\right)=(\hat{y}\boldsymbol{E}_{\boldsymbol{x}}) \qquad (5.3)$$

Solusi fungsi periodik Sinusoidal $\mathbf{H}=\mathbf{H_0}\mathrm{e}^{(-i\omega t-kz)}$

$$\nabla\times\mathbf{E}=-\frac{\partial\mathbf{B}}{\partial \mathrm{t}}$$

$$\nabla\times\mathbf{E}=-\mu\frac{\partial\mathbf{H}}{\partial \mathrm{t}}$$

$$\nabla\times\mathbf{E}=-\mu\frac{\partial(\mathrm{e}^{i\omega t})}{\partial \mathrm{t}}$$

$$\nabla\times\mathbf{E}=-\mu i\omega.\,\mathrm{e}^{i\omega t}$$

$$\nabla\times\mathbf{E}=-\mu\mathrm{i}\omega.\,\mathbf{H} \qquad (5.4)$$

$$\left(\frac{\partial}{\partial \mathrm{x}}\hat{\imath}+\frac{\partial}{\partial \mathrm{y}}\hat{\jmath}+\frac{\partial}{\partial \mathrm{z}}\hat{k}\right)\times\left(\mathbf{E}_{\mathrm{x}}\hat{\imath}+\mathbf{E}_{\mathrm{y}}\hat{\jmath}+\mathbf{E}_{\mathrm{z}}\hat{k}\right)=-\mathrm{i}\omega\mu(\mathbf{E}_{\mathrm{x}}\hat{\imath}+\mathbf{E}_{\mathrm{y}}\hat{\jmath}+\mathbf{E}_{\mathrm{z}}\hat{k})$$

$$\begin{vmatrix}\hat{\imath} & \hat{\jmath} & \hat{k}\\ \frac{\partial}{\partial \mathrm{x}} & \frac{\partial}{\partial \mathrm{y}} & \frac{\partial}{\partial \mathrm{z}}\\ \mathbf{E}_{\mathrm{x}} & \mathbf{E}_{\mathrm{y}} & \mathbf{E}_{\mathrm{z}}\end{vmatrix}\begin{vmatrix}\hat{\imath} & \hat{\jmath}\\ \frac{\partial}{\partial \mathrm{x}} & \frac{\partial}{\partial \mathrm{y}}\\ \mathbf{E}_{\mathrm{x}} & \mathbf{E}_{\mathrm{y}}\end{vmatrix}$$

$$\hat{\imath}\left(\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{y}}-\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{z}}\right)+\hat{\jmath}\left(\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{z}}-\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{x}}\right)+\hat{k}\left(\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{x}}-\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{y}}\right)=-\mathrm{i}\omega\mu(\mathbf{H}_{\mathrm{x}}\hat{\imath}+\mathbf{H}_{\mathrm{y}}\hat{\jmath}+\mathbf{H}_{\mathrm{z}}\hat{k})$$

Jadi, dapat diperoleh hubungan berikut:

$$\left(\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{y}}-\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{z}}\right)\hat{\imath}=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{x}}\hat{\boldsymbol{\imath}}$$

$$\left(\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{y}}-\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{z}}\right)=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{x}} \qquad (5.5a)$$

$$\left(\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{z}}-\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{x}}\right)\hat{\jmath}=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{y}}\hat{\boldsymbol{\jmath}}$$

$$\left(\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{z}}-\frac{\partial\mathbf{E}_{\mathrm{z}}}{\partial \mathrm{x}}\right)=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{y}} \qquad (5.5b)$$

$$\left(\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{x}}-\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{y}}\right)=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{z}}\hat{\mathbf{k}}$$

$$\left(\frac{\partial\mathbf{E}_{\mathrm{y}}}{\partial \mathrm{x}}-\frac{\partial\mathbf{E}_{\mathrm{x}}}{\partial \mathrm{y}}\right)\hat{k}=-\mathrm{i}\omega\mu\mathbf{H}_{\mathbf{z}} \qquad (5.5c)$$

Karena medan listrik merambat dalam arah sumbu x, maka komponen E_y dan E_z dan dapat diabaikan, sehingga diperoleh:

$$\left(\frac{\partial \mathbf{E_z}}{\partial y} - \frac{\partial \mathbf{E_y}}{\partial z}\right) = -i\omega\mu\mathbf{H_x}$$

$$\left(\frac{\partial \mathbf{E_x}}{\partial z} - \frac{\partial \mathbf{E_z}}{\partial x}\right) = -i\omega\mu\mathbf{H_y}$$

$$\left(\frac{\partial \mathbf{E_y}}{\partial x} - \frac{\partial \mathbf{E_x}}{\partial y}\right) = -i\omega\mu\mathbf{H_z}$$

Menjadi:

$$0 = -i\omega\mu\mathbf{H_x}$$

$$\left(\frac{\partial \mathbf{E_x}}{\partial z} - 0\right) = -i\omega\mu\mathbf{H_y}$$

$$\left(0 - \frac{\partial \mathbf{E_x}}{\partial y}\right) = -i\omega\mu\mathbf{H_z}$$

Dengan $\hat{z} = i\omega\mu$, maka:

$$-\frac{\partial \mathbf{E_x}}{\partial y} = -i\omega\mu\mathbf{H_z}$$

$$-\frac{\partial \mathbf{E_x}}{\partial y} = -\hat{z}\mathbf{H_z} \qquad (5.6a)$$

$$\frac{\partial \mathbf{E_x}}{\partial z} = -i\omega\mu\mathbf{H_y}$$

$$\frac{\partial \mathbf{E_x}}{\partial z} = -\hat{z}\mathbf{H_y} \qquad (5.6b)$$

$$\mathbf{H}_y = -\frac{1}{\hat{z}}\frac{\partial \mathbf{E_x}}{\partial z}$$

$$\mathbf{H}_y = -\frac{1}{i\omega\mu}\frac{\partial \mathbf{E_x}}{\partial z}$$

B. Mode *Transverse Magnetic* (TM)

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{E} = -\mu\frac{\partial \mathbf{H}}{\partial t}$$

$$\nabla \times \mathbf{E} = -\mu\frac{\partial(e^{i\omega t})}{\partial t}$$

$$\nabla \times \mathbf{E} = -\mu i\omega . e^{i\omega t}$$

$$\nabla \times \mathbf{E} = -\mu i\omega . \mathbf{H} \qquad (5.7)$$

$$\left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right) \times \left(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k}\right) = -i\omega\mu(\mathbf{H}_x\hat{\imath}\hat{y} + \mathbf{H}_y\hat{\jmath}\hat{y} + \mathbf{H}_z\hat{k}\hat{y})$$

$$\begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \mathbf{E}_x & \mathbf{E}_y & \mathbf{E}_z \end{vmatrix} \begin{vmatrix} \hat{\imath} & \hat{\jmath} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} \\ \mathbf{E}_x & \mathbf{E}_y \end{vmatrix}$$

$$\hat{\imath}\left(\frac{\partial \mathbf{E}_z}{\partial y} - \frac{\partial \mathbf{E}_y}{\partial z}\right) + \hat{\jmath}\left(\frac{\partial \mathbf{E}_x}{\partial z} - \frac{\partial \mathbf{E}_z}{\partial x}\right) + \hat{k}\left(\frac{\partial \mathbf{E}_y}{\partial x} - \frac{\partial \mathbf{E}_x}{\partial y}\right) = -i\omega\mu(\mathbf{H}_x\hat{\imath}\hat{y} + \mathbf{H}_y\hat{\jmath}\hat{y} + \mathbf{H}_z\hat{k}\hat{y})$$

Karena medan magnet merambat dalam arah sumbu $x(\hat{\imath})$, maka komponen $y(\hat{\jmath})$, dan $z(\hat{k})$ bernilai nol. Sehingga diperoleh:

$$\left(\frac{\partial \mathbf{E}_z}{\partial y} - \frac{\partial \mathbf{E}_y}{\partial z}\right)\hat{\imath} + (0-0)\hat{\jmath} + (0-0)\hat{k} = -i\omega\mu(\mathbf{H}_x\hat{\imath}\hat{y} + \mathbf{H}_y\hat{\jmath}\hat{y} + \mathbf{H}_z\hat{k}\hat{y})$$

$$\left(\frac{\partial \mathbf{E}_z}{\partial y} - \frac{\partial \mathbf{E}_y}{\partial z}\right)\hat{\imath} = -i\omega\mu(\mathbf{H}_x\hat{\imath}\hat{y})$$

Diasumsikan $\hat{z} = -i\omega\mu$, menjadi:

$$\left(\frac{\partial \mathbf{E}_z}{\partial y} - \frac{\partial \mathbf{E}_y}{\partial z}\right) = \hat{z}(\mathbf{H}_x\hat{y})$$

$$\nabla \times \mathbf{H} = \mathbf{E}\hat{y}$$

$$\left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right) \times \left(\mathbf{H}_x\hat{\imath} + \mathbf{H}_y\hat{\jmath} + \mathbf{H}_z\hat{k}\right) = \hat{y}(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k})$$

$$\begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \mathbf{H}_x & \mathbf{H}_y & \mathbf{H}_z \end{vmatrix} \begin{vmatrix} \hat{\imath} & \hat{\jmath} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} \\ \mathbf{H}_x & \mathbf{H}_y \end{vmatrix}$$

$$\hat{\imath}\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right) + \hat{\jmath}\left(\frac{\partial \mathbf{H}_x}{\partial z} - \frac{\partial \mathbf{H}_z}{\partial x}\right) + \hat{k}\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}(\mathbf{E}_x\hat{\imath} + \mathbf{E}_y\hat{\jmath} + \mathbf{E}_z\hat{k})$$

Sehingga diperoleh:

$$\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right)\hat{\imath} = \hat{y}\mathbf{E_x}\hat{\mathbf{\imath}}$$

$$\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right) = \hat{y}\mathbf{E_x} \qquad (5.8a)$$

$$\left(\frac{\partial \mathbf{H}_x}{\partial y} - \frac{\partial \mathbf{H}_z}{\partial x}\right)\hat{\jmath} = \hat{y}\mathbf{E_y}\hat{\mathbf{\jmath}}$$

$$\left(\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right) = \hat{y}\mathbf{E_y} \qquad (5.8b)$$

$$\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}\mathbf{E_z}\hat{k}$$

$$\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}\mathbf{E_z} \quad (5.8c)$$

Karena medan listrik merambat dalam arah sumbu x, maka komponen H_y dan H_z bernilai nol, sehingga diperoleh:

$$\frac{\partial \mathbf{H}_z}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z} = \hat{y}\mathbf{E_x}\hat{\mathbf{i}}$$

$$0 - 0 = \hat{y}\mathbf{E_x}$$

$$\frac{\partial \mathbf{H}_x}{\partial z} - \frac{\partial \mathbf{H}_z}{\partial x} = \hat{y}\mathbf{E_y}$$

$$\frac{\partial \mathbf{H}_x}{\partial z} - 0 = \hat{y}\mathbf{E_y}$$

$$\frac{\partial \mathbf{H}_x}{\partial z} = \hat{y}\mathbf{E_y} \quad (5.9a)$$

$$\left(\frac{\partial \mathbf{H}_y}{\partial x} - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}\mathbf{E_z}$$

$$\left(0 - \frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}\mathbf{E_z}$$

$$\left(-\frac{\partial \mathbf{H}_x}{\partial y}\right) = \hat{y}\mathbf{E_z} \quad (5.9b)$$

Pada pemodelan 2D, yang mana tahanan jenis berubah terhadap sumbu y dan z. Komponen medan listrik $\mathbf{E}_x$ pada mode TE diperoleh:

$$\frac{\partial \mathbf{E}_x}{\partial z} = -\hat{z}\mathbf{H_y}$$

$$\frac{\partial^2 \mathbf{E}_x}{\partial z^2} = -\frac{\partial \hat{z}\mathbf{H}_y}{\partial z}$$

$$-\frac{\partial \mathbf{E}_x}{\partial y} = -\hat{z}\mathbf{H_z}$$

$$\frac{\partial \mathbf{E}_x}{\partial y} = \hat{z}\mathbf{H_z}$$

$$\frac{\partial^2 \mathbf{E}_x}{\partial y^2} + \frac{\partial^2 \mathbf{E}_x}{\partial z^2} = \frac{\partial \hat{z}\mathbf{H}_x}{\partial y} - \frac{\partial \hat{z}\mathbf{H}_y}{\partial z}$$

$$\frac{\partial^2 \mathbf{E}_x}{\partial y^2} + \frac{\partial^2 \mathbf{E}_x}{\partial z^2} = \left(\frac{\partial \mathbf{H}_x}{\partial y} - \frac{\partial \mathbf{H}_y}{\partial z}\right)\hat{z}$$

$$\frac{\partial^2 \mathbf{E}_x}{\partial y^2} + \frac{\partial^2 \mathbf{E}_x}{\partial z^2} = \hat{z}\hat{y}\mathbf{E_x} \quad (5.10)$$

Sedangkan komponen medan magnet $\mathbf{H_x}$ pada mode TM diperoleh:

$$\frac{\partial \mathbf{H}_x}{\partial z} = \hat{y}\mathbf{E}_y \quad (5.11)$$

$$\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z} = \hat{y}\mathbf{E}_y$$

$$\frac{\partial}{\partial z}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z}\right) = \frac{\partial \mathbf{E}_y}{\partial z}$$

$$\frac{\partial \mathbf{H}_x}{\partial y} = -\hat{y}\mathbf{E}_y$$

$$-\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial y} = \mathbf{E}_z$$

$$-\frac{\partial}{\partial z}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial y}\right) = \frac{\partial \mathbf{E}_z}{\partial z}$$

Maka diperoleh:

$$-\frac{\partial}{\partial y}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial y}\right) - \frac{\partial}{\partial z}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z}\right) = \frac{\partial \mathbf{E}_z}{\partial y} - \frac{\partial \mathbf{E}_y}{\partial z}$$

$$-\frac{\partial}{\partial y}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial y}\right) - \frac{\partial}{\partial z}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z}\right) = -\hat{z}\mathbf{H}_{\boldsymbol{x}}$$

$$\frac{\partial}{\partial y}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial y}\right) - \frac{\partial}{\partial z}\left(\frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z}\right) = \hat{z}\mathbf{H}_{\boldsymbol{x}} \quad (5.11)$$

Menjadi:

$$\frac{\partial \mathbf{H}_x}{\partial z} = \hat{y}\boldsymbol{E}_y$$

$$\mathbf{E}_y = \frac{1}{\hat{y}}\frac{\partial \mathbf{H}_x}{\partial z}$$

$$\mathbf{E}_y = \frac{1}{\sigma}\frac{\partial \mathbf{H}_x}{\partial z}$$

Lampiran 6: Transformasi Fourier

Transformasi fourier merupakan suatu fungsi yang dapat mengubah sinyal dari *time series* menjadi domain frekuensi. Suatu isyarat periodis dengan periode T_0, dapat dinyatakan sebagai berikut:

$$x(t) = a_0 + \sum_{k=-\infty}^{+\infty} ak.e^{ik\omega t} + ak.e^{ik\omega t} \quad (6.1)$$

Dengan,

$T_0 = \frac{2\pi}{\omega_0}$ = fungsi fundamental

ω_0 = frekuensi sudut

$f_0 = \frac{1}{T_0}$ = koefisien deret fourier

Sehingga:

$$ak = \frac{1}{T_0}\int_{T_0/2}^{T_0/2} x(t).e^{-ik\omega t}dt$$

Menjadi:

$$T_0 ak = \int_{T_0/2}^{T_0/2} x(t).e^{-ik\omega t}dt$$

Ketika T_0 nilainya bertambah besar dan ω menjadi mengecil, maka jarak antar koefisien fourier menjadi semakin kecil juga (merapat).

$$T_0 \to \infty$$

Sehingga,

$$T_0 ak = \int_{-\infty}^{\infty} x(t).e^{-ik\omega t}dt$$

Dengan $x(\omega) = T_0 ak$ dan $\omega = k\omega$

Maka,

$$x(\omega) = \int_{-\infty}^{\infty} x(t).e^{-ik\omega t}dt$$

Sebagaimana terlihat, fungsi aperiodik dilihat sebagai fungsi periodik.

$T_0 = \frac{2\pi}{\omega_0}$ = fungsi fundamental

$\omega = k\omega$

Sehingga:

$$ak = \frac{1}{T_0} x(k\omega) = \frac{1}{T_0} X(\omega)$$

Maka persamaan transformasi fourier akan menjadi seperti berikut:

$$x(t) = \sum_{k=-\infty}^{+\infty} \frac{1}{T_0} X(\omega) e^{i\omega t}$$

$$x(t) = \frac{1}{2\pi} \sum_{k=-\infty}^{+\infty} X(\omega) e^{i\omega t} d\omega$$

Kemudian ketika diintergralkan menjadi:

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} x(\omega) e^{i\omega t} d\omega \qquad (6.2)$$

$$x(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} dt \qquad (6.3)$$

Lampiran 7: Inversi Occam 1 Dimensi

Hubungan antara data dengan parameter model:

$$d = G(m) \tag{7.1}$$

Solusi untuk model m yang merupakan model awal (m_0) yang diperturbasi dengan Δm agar diperoleh misfit yang lebih baik. Maka m adalah:

$$m = m_0 + \Delta m$$

Disubtitusikan:

$$d = G(m_0 + \Delta m)$$

Jika dituliskan kembali dalam bentuk komponennya maka diperoleh:

$$d_i = G_i(m_0^{(j)} + \delta m_j)$$

Dimana, I = 1, 2, 3, …, N dan j = 1, 2, 3, …, M dengan N dan M masing-masing yaitu jumlah data dan jumlah parameter model.

Ekspansi Taylor orde pertama fungsi G(m) adalah sebagai berikut:

$$G_i\left(m_0^{(j)} + \partial m_j\right) \approx G_i\left(m_0^{(j)} + \frac{\partial G_i}{\partial m_j}\right) \partial m_j + 0(\partial m_j)$$

Dimana $0(\partial m_j)$ merupakan suku sisa yang melibatkan turunan orde kedua dan orde yang lebih tinggi. Setelah disubtitusikan persamaannya menjadi:

$$d = G_i\left(m_0^{(j)} + \frac{\partial G_i}{\partial m_j}\right) \partial m_j$$

Suku kedua pada ruas kanan merupakan komponen turunan parsial fungsi g(m) terhadap suatu elemen parameter model m yang membentuk matriks Jacobi berikut:

$$J_{ij} = \frac{\partial G_i}{\partial m_j}$$

Hasil subtitusinya:

$$d - G(m_0) = \underline{J}_0 \Delta m_0$$

Atau,

$$\Delta d_0 = \underline{J}_0 \Delta m_0$$

Dimana,

$\underline{J}_0$: matriks Jacobi yang dievaluasi pada $m = m_0$

_ : symbol bilangan kompleks

Selanjutnya,

$$\Delta d_0 = d - G(m_0) \text{ dan } \Delta m_0$$

Untuk memperoleh solusi inversi atau model optimum diperlukan perturbasi secara iteratif suatu model awal m_0. Dengan demikian pada iterasi ke-(n+1) perturbasi dilakukan terhadap model hasil iterasi sebelumnya dengan menggunakan persamaan berikut:

$$m_{n+1} = m_n + \left[\underline{J}_\mathrm{n}^T \underline{J}_\mathrm{n}\right]^{-1} \underline{J}_\mathrm{n}^T (d - G(m_\mathrm{n}))$$

Metode Occam merupakan pengembangan dari metode Levenberg-marquardt dengan menambahkan parameter delta untuk smoothing berdasarkan regulasi tikhonov orde 1.

$$L = \begin{bmatrix} 0 & 0 & & & \\ -1 & 1 & & & \\ & -1 & 1 & & \\ & & \cdots & & \\ & & -1 & 1 \end{bmatrix}_{mxn} \qquad (7.2)$$

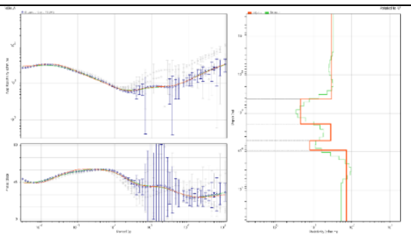
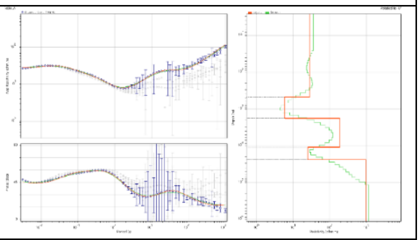
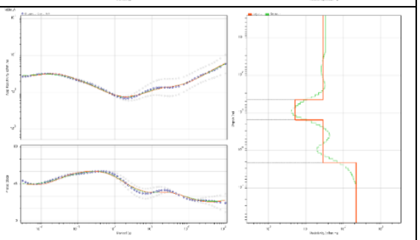
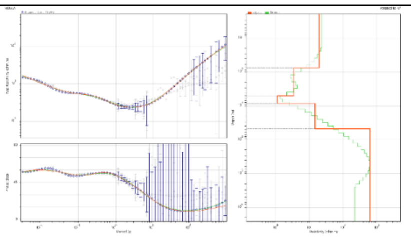
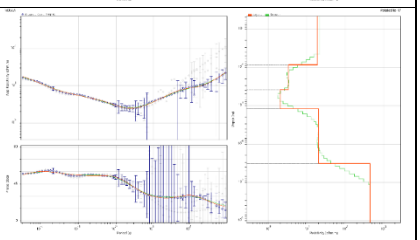
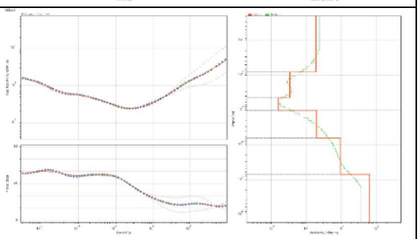
Sehingga parameter model menjadi:

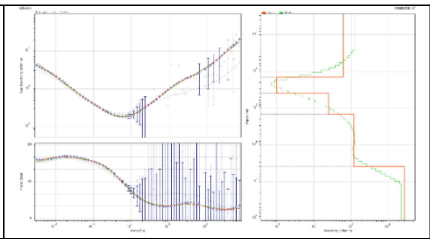
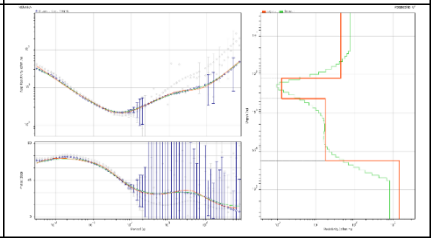
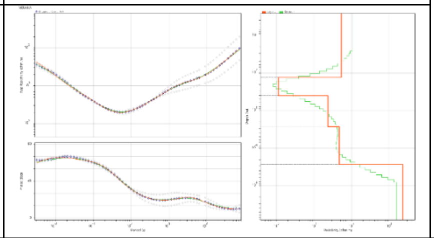
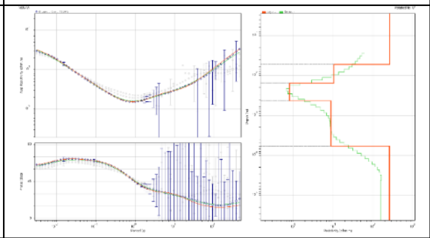
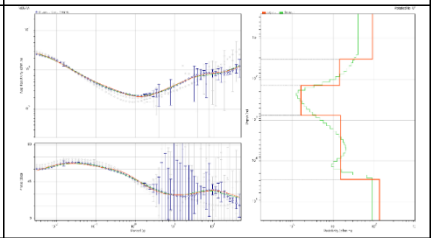
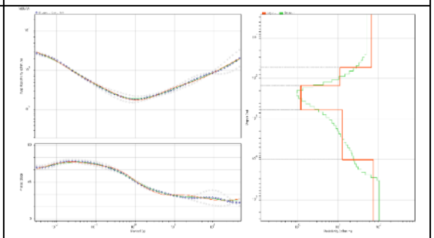
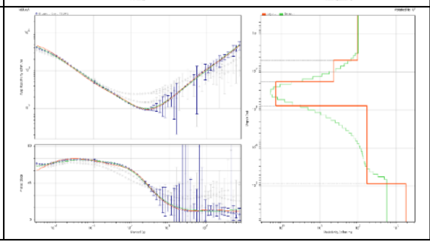
$$\hat{d} = d - g(m_n) + \underline{J}_n m_n \qquad (7.3a)$$

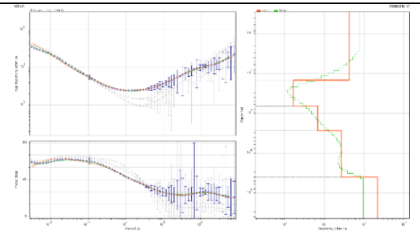
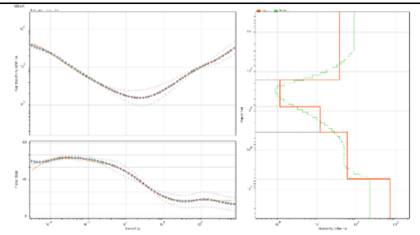
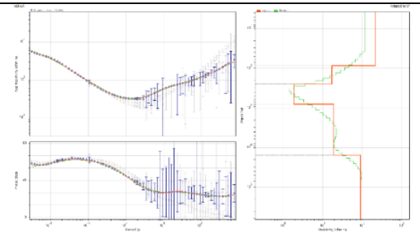
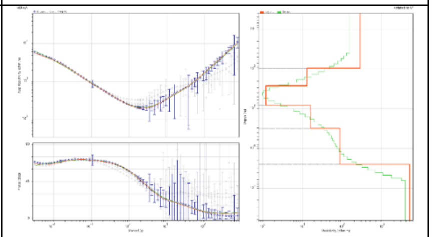
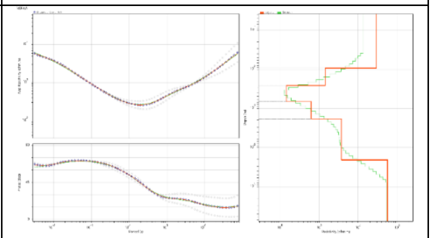
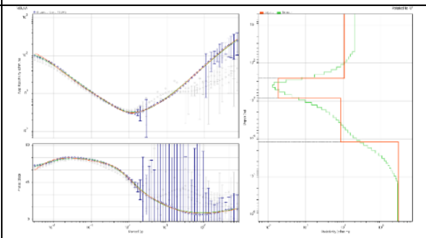
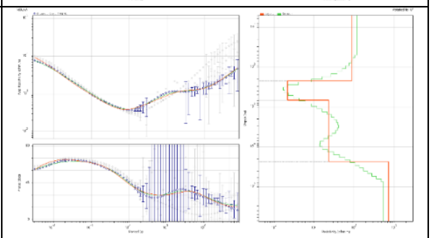
$$m_{n+1} = [\underline{J}_n^T \underline{J}_n + \alpha^2 L^T L]^{-1} \underline{J}_n^T \hat{d} \qquad (7.3b)$$

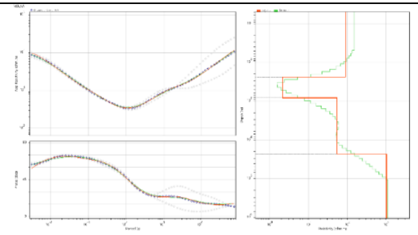
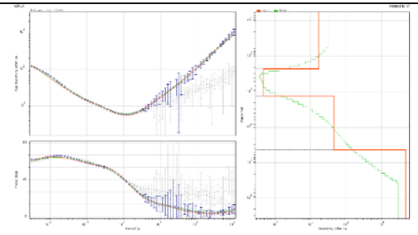
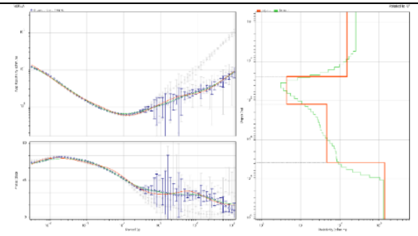
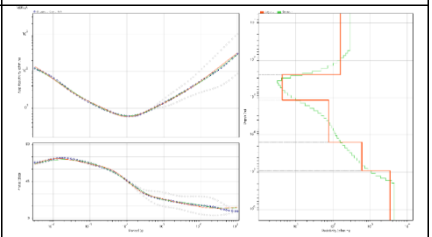
Lampiran 8: Hasil inversi 1D

A. Lintasan NS02

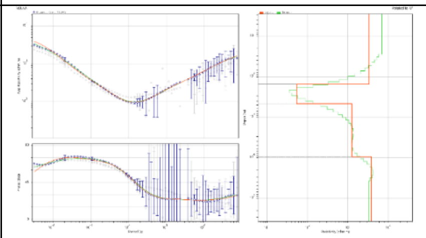
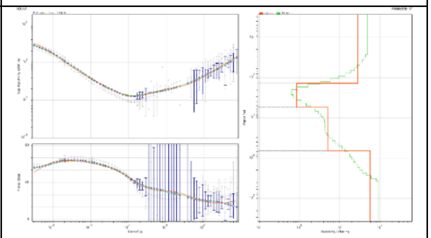
Titik Pengukuran	Mode	Hasil	Lapisan (n)
M095	TE		5 lapisan
	TM		
	INV		
M086	TE		5 lapisan
	TM		
	INV		

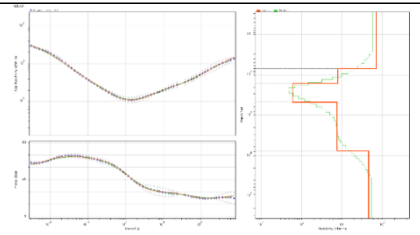
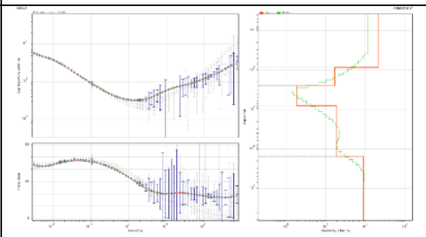
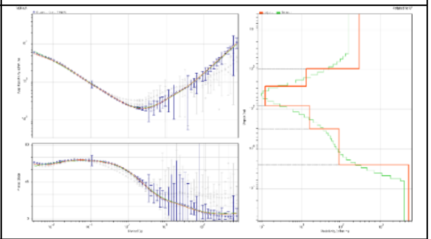
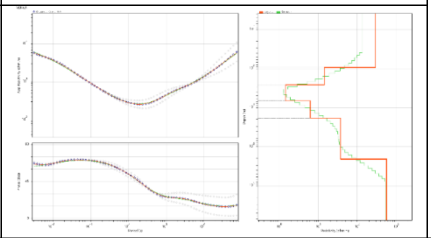
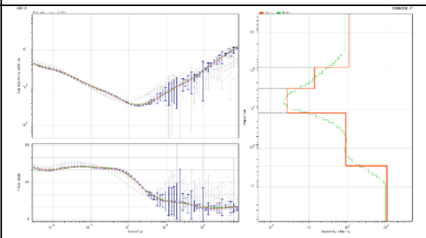
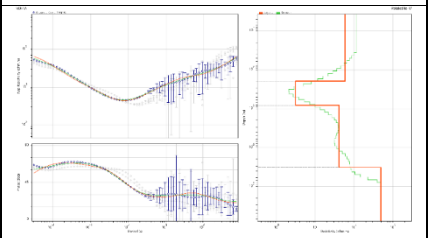
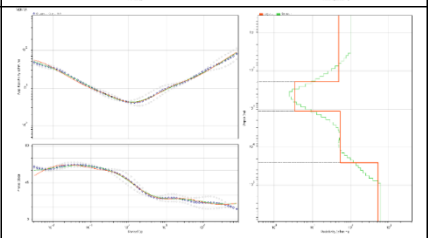
M069	TE		4 lapisan
	TM		
	INV		
M061	TE		5 lapisan
	TM		
	INV		
M050	TE		5 lapisan

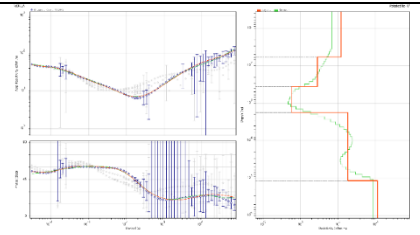
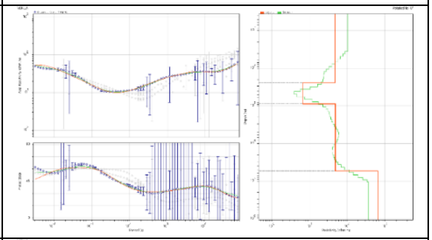
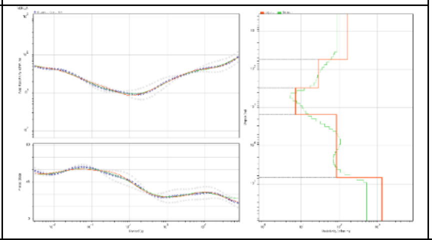
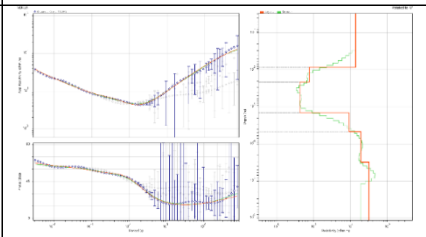
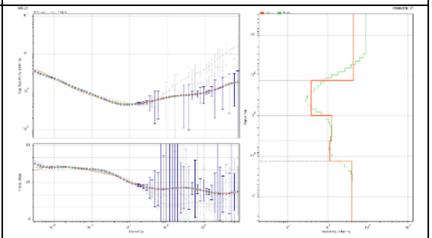
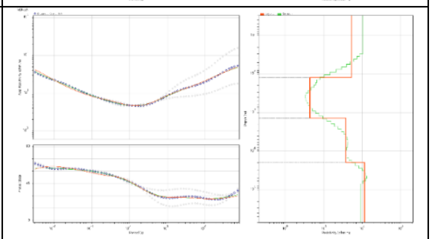
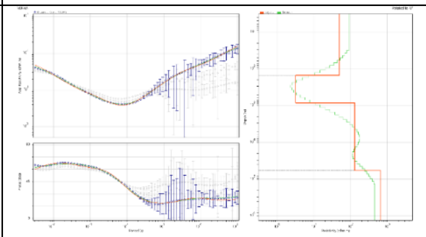
	TM		
	INV		
	TE		
M040	TM		6 lapisan
	INV		
M029	TE		4 lapisan
	TM		

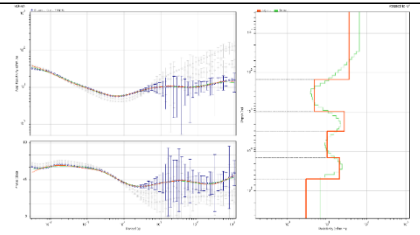
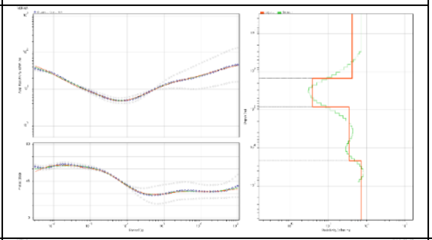
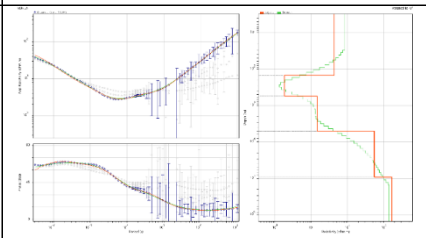
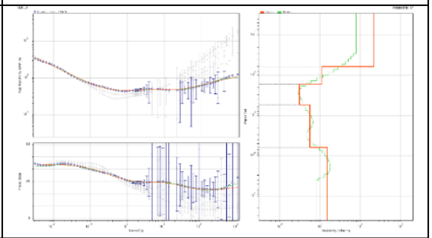
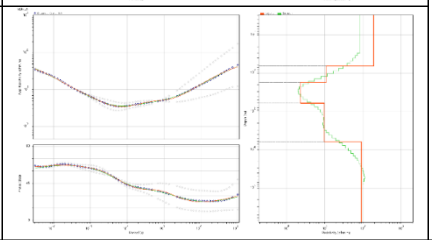
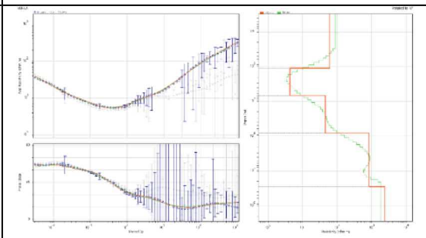
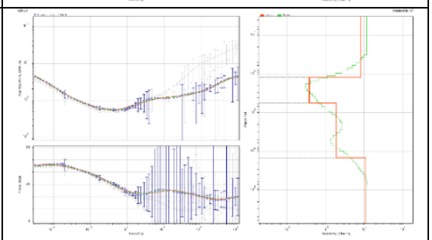
	INV		
M018	TE		4 lapisan
	TM		
	INV		

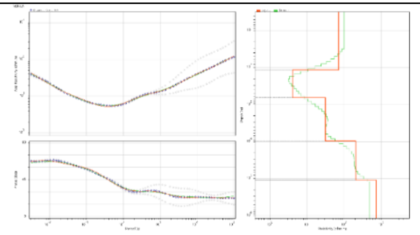
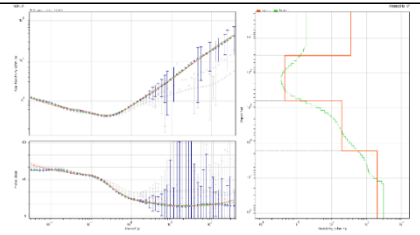
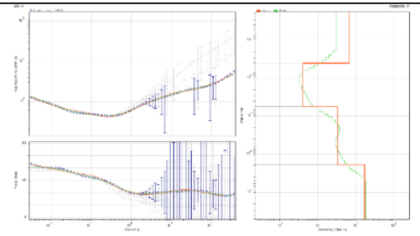
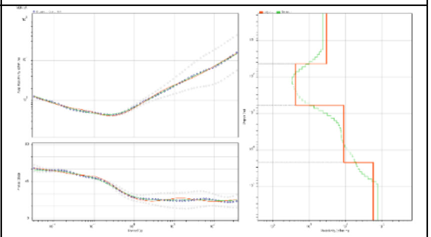
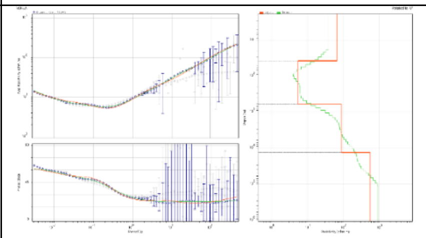
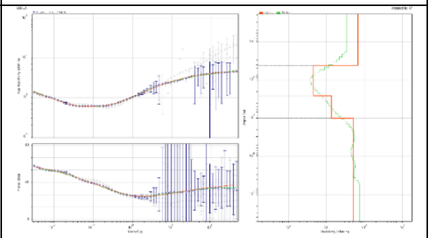
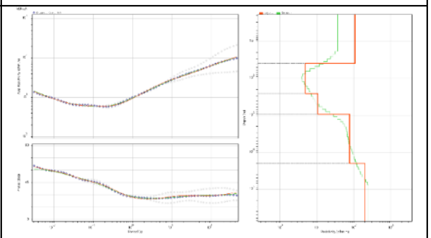
B. Lintasan WS07

Titik Pengukuran	Mode	Hasil	Lapisan (n)
M039	TE		4 lapisan
	TM		

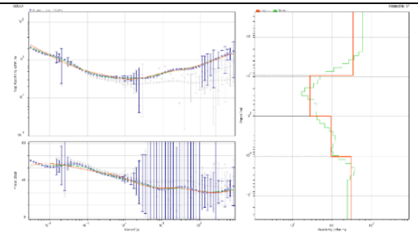
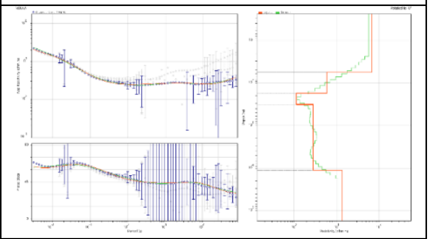
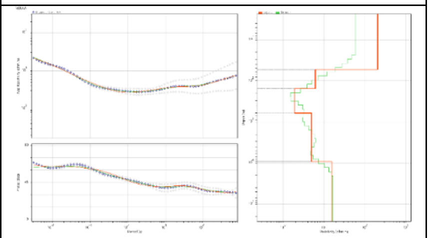
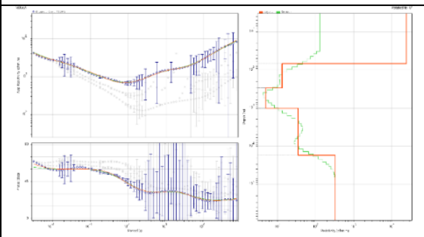
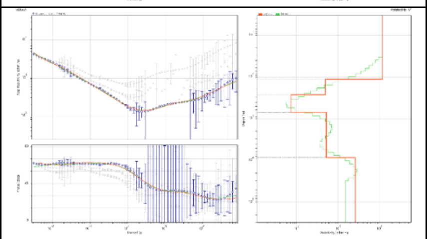
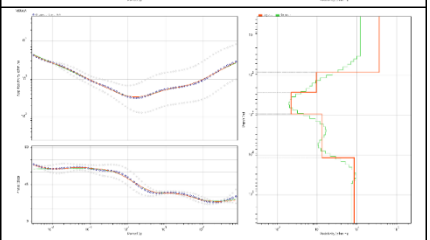
	INV		
M040	TE		6 lapisan
	TM		
	INV		
M041	TE		4 lapisan
	TM		
	INV		

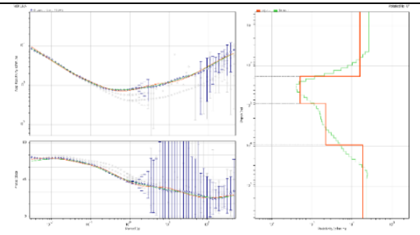
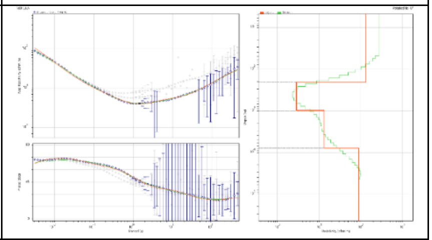
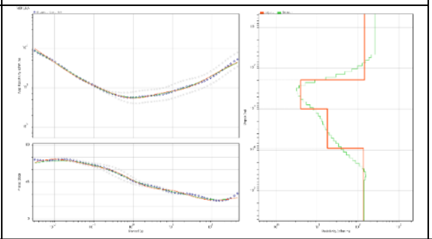
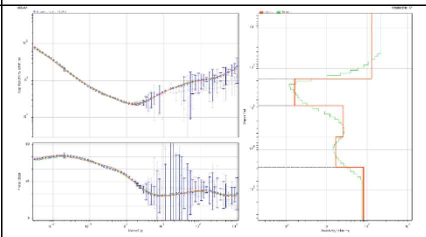
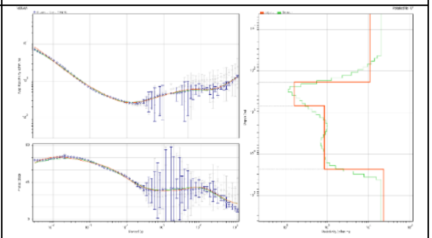
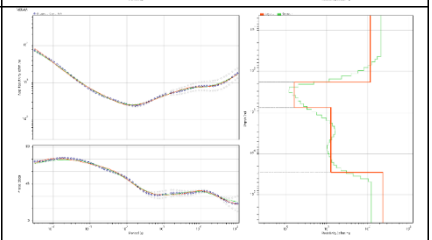
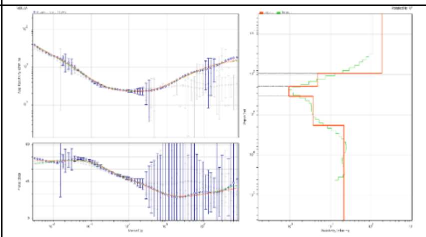
M042	TE		4 lapisan
	TM		
	INV		
M043	TE		5 lapisan
	TM		
	INV		
M044	TE		6 lapisan

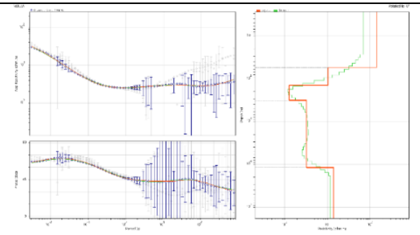
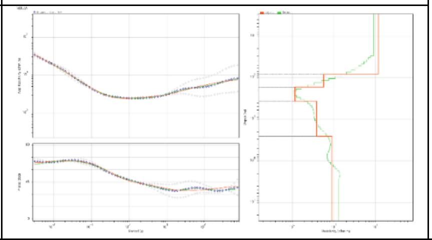
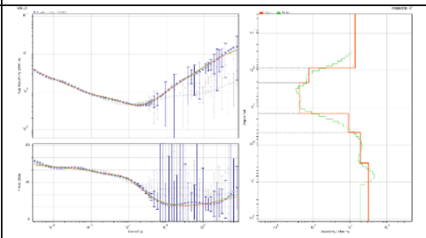
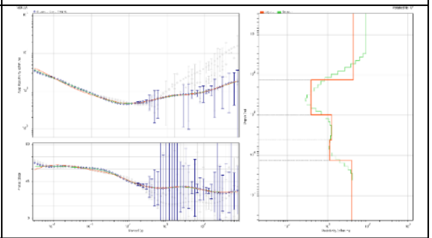
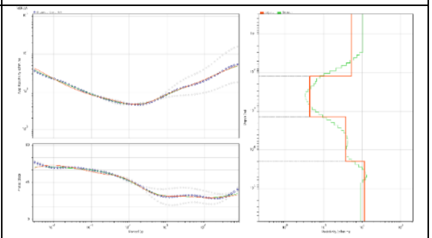
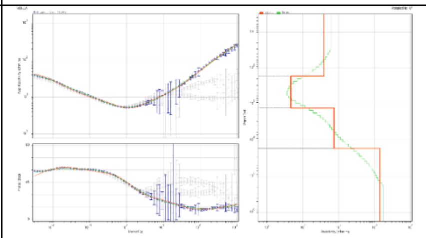
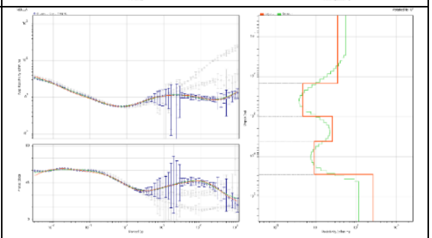
	TM		
	INV		
M045	TE		5 lapisan
	TM		
	INV		
M046	TE		4 lapisan
	TM		

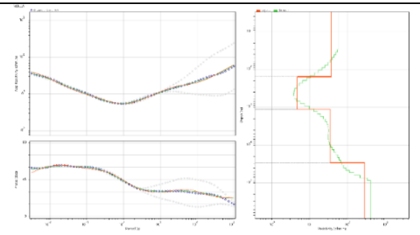
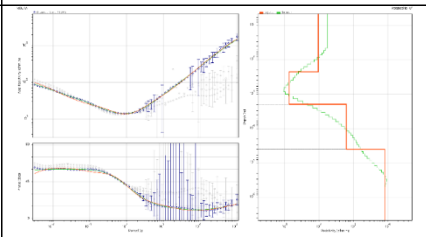
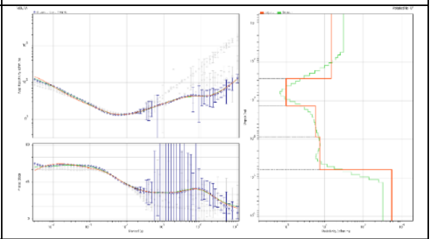
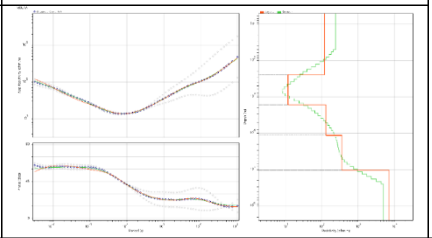
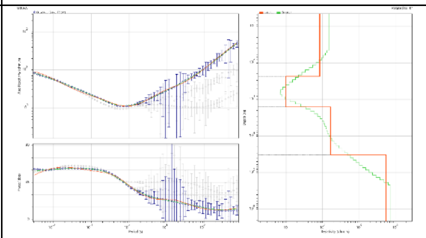
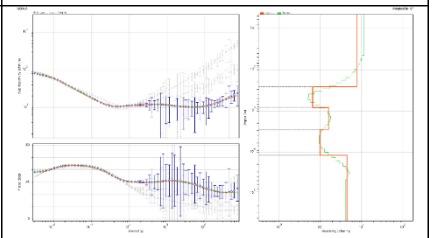
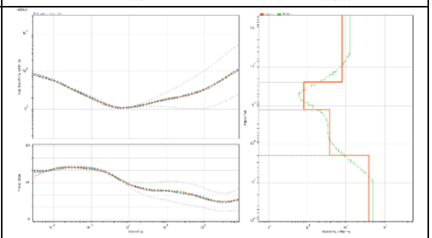
	INV		
	TE		
M047	TM		4 lapisan
	INV		
	TE		
M048	TM		4 lapisan
	INV		

C. Lintasan NS05

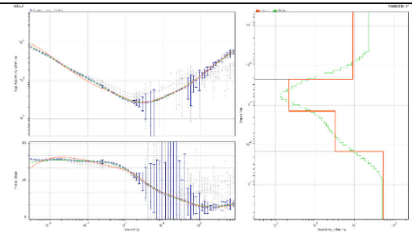
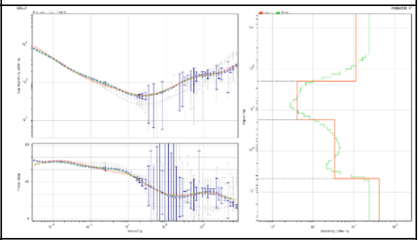
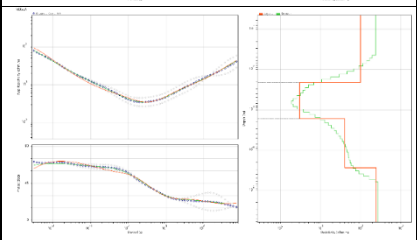
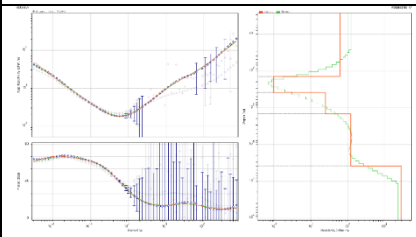
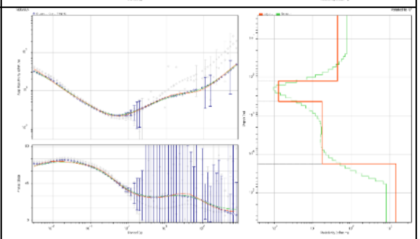
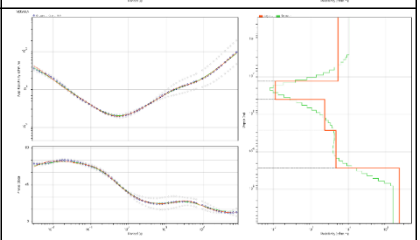
Titik Pengukuran	Mode	Hasil	Lapisan (n)
M089	TE		5 lapisan
	TM		
	INV		
M080	TE		5 lapisan
	TM		
	INV		

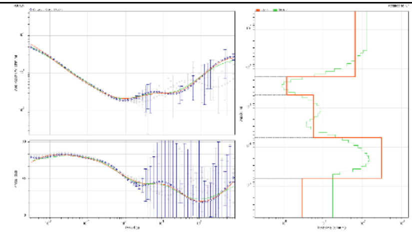
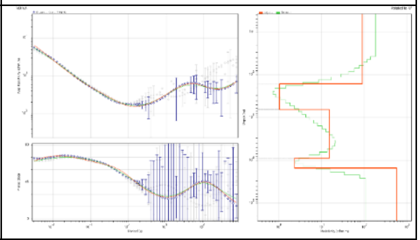
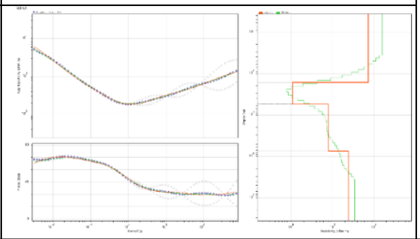
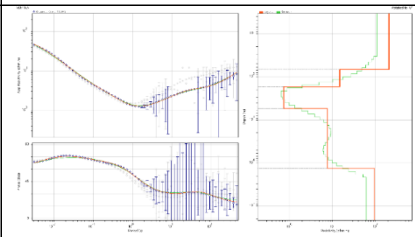
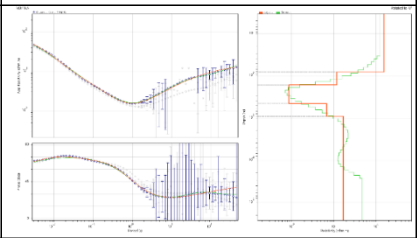
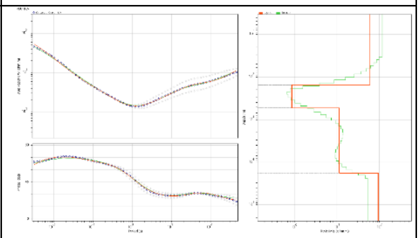
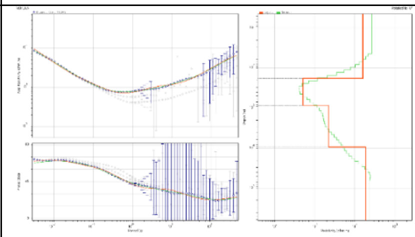
M072	TE		4 lapisan
	TM		
	INV		
M064	TE		4 lapisan
	TM		
	INV		
M053	TE		5 lapisan

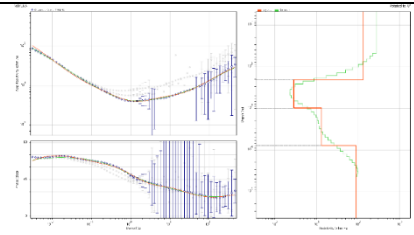
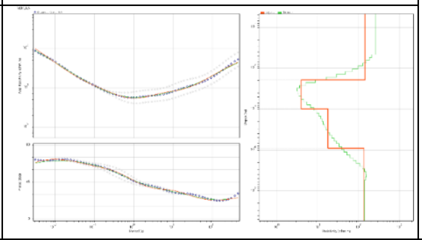
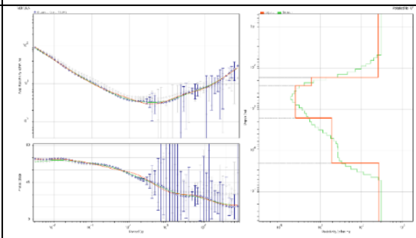
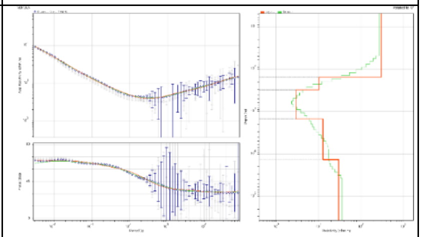
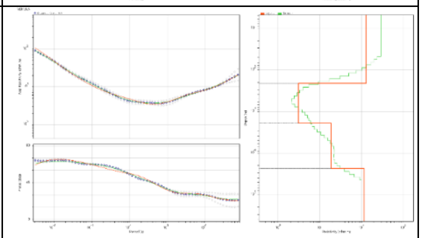
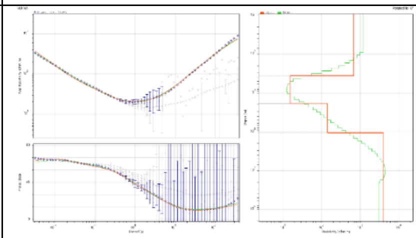
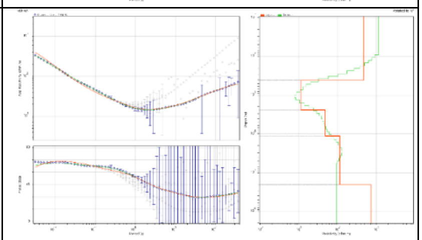
	TM		
	INV		
	TE		
M043	TM		5 lapisan
	INV		
M032	TE		5 lapisan
	TM		

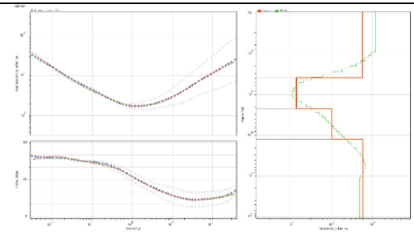
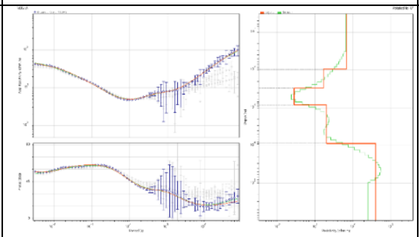
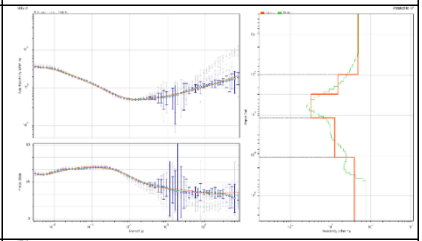
	INV		
	TE		
M021	TM		6 lapisan
	INV		
	TE		
M009	TM		5 lapisan
	INV		

D. Lintasan WE04

Titik Pengukuran	Mode	Hasil	Lapisan (n)
M068	TE		4 lapisan
	TM		
	INV		
M069	TE		4 lapisan
	TM		
	INV		

M070	TE		5 lapisan
	TM		
	INV		
M071	TE		5 lapisan
	TM		
	INV		
M072	TE		4 lapisan

	TM		
	INV		
M073	TE		4 lapisan
	TM		
	INV		
M074	TE		5 lapisan
	TM		

	INV		
M067	TE		5 lapisan
	TM		
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