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LAMPIRAN

Hasil MT Editor tiap titik

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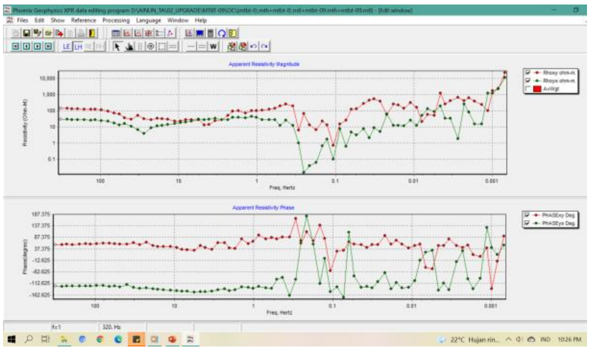

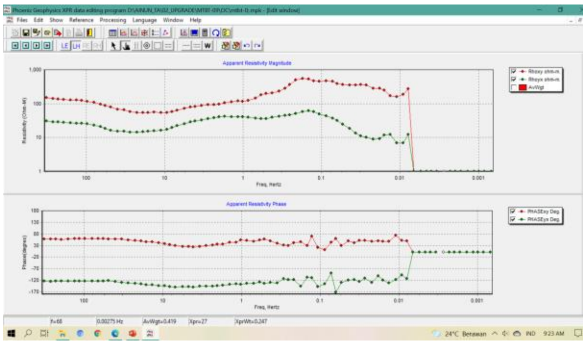

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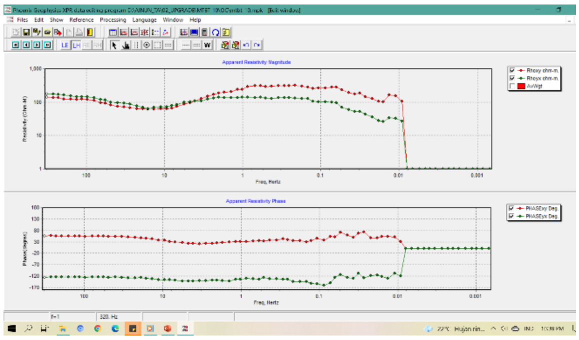

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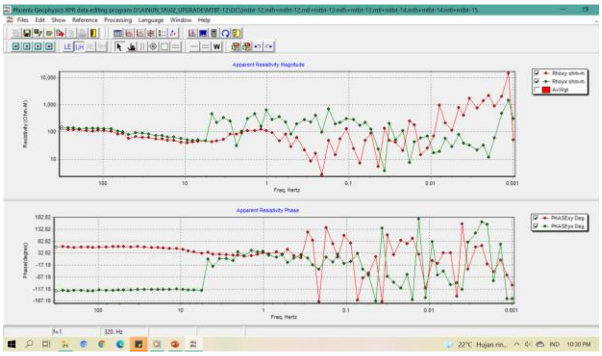

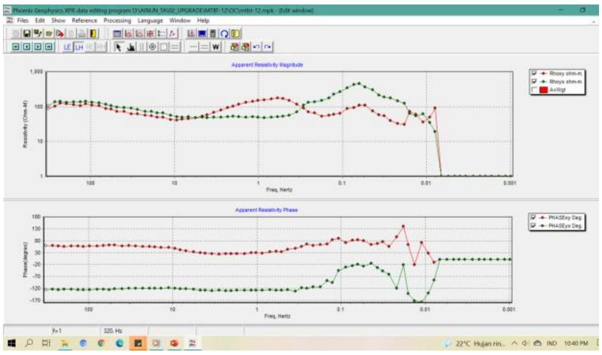

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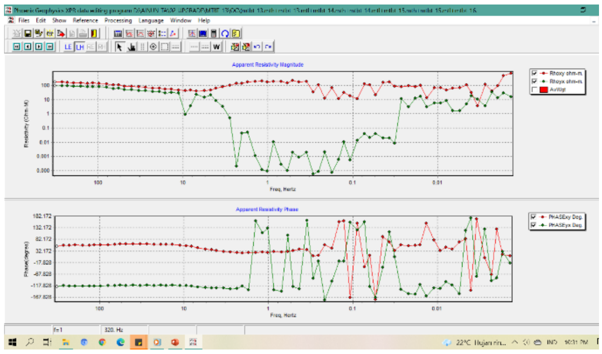

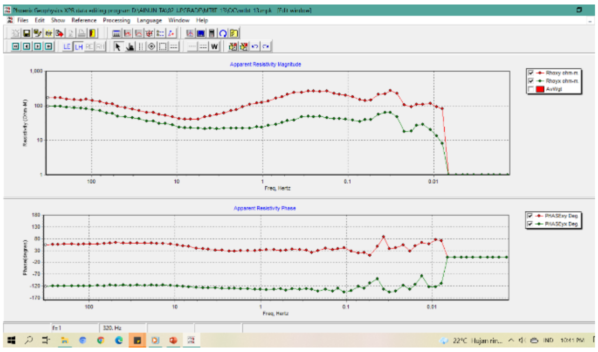

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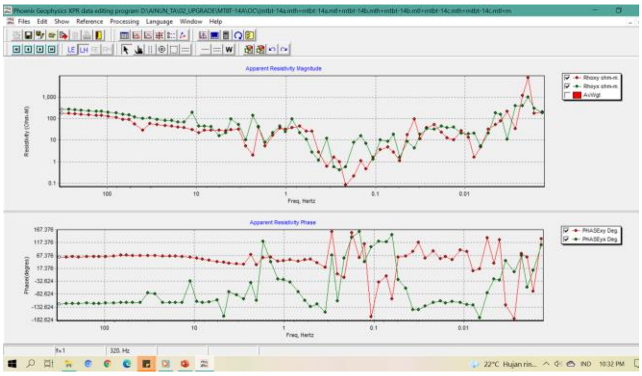

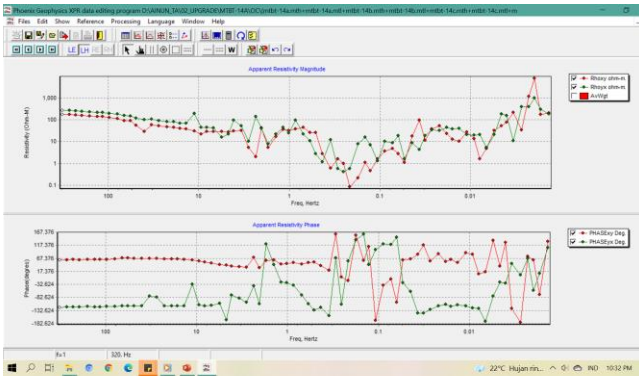

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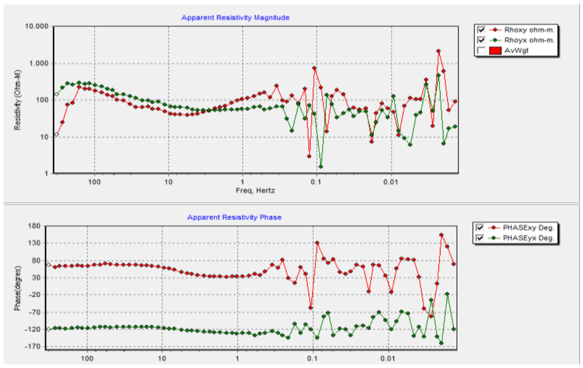

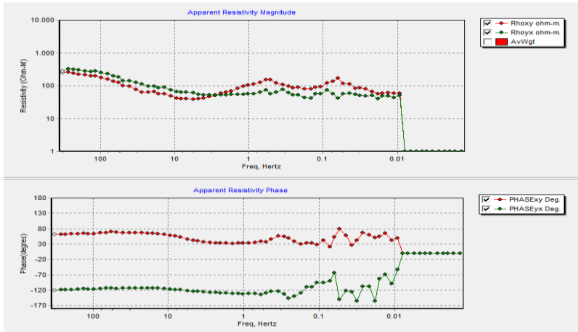

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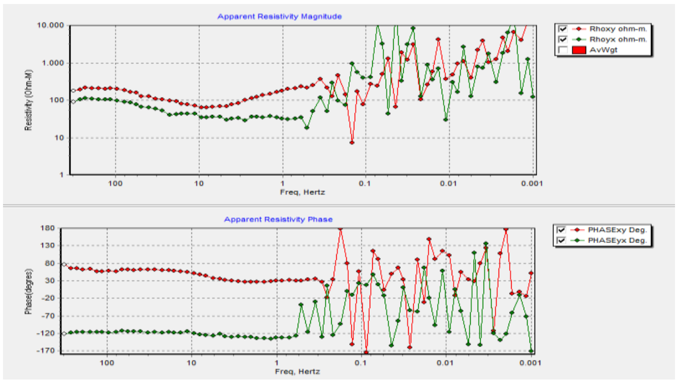

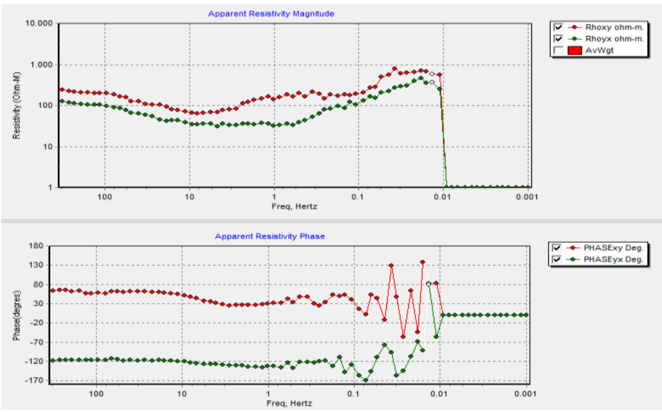

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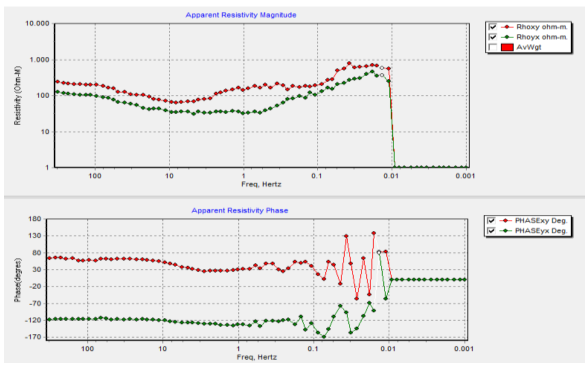

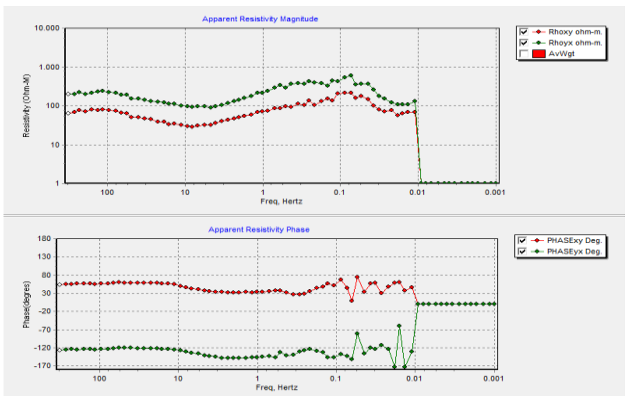

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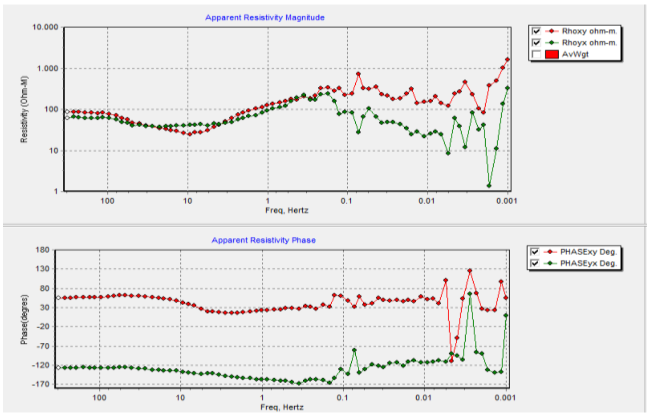

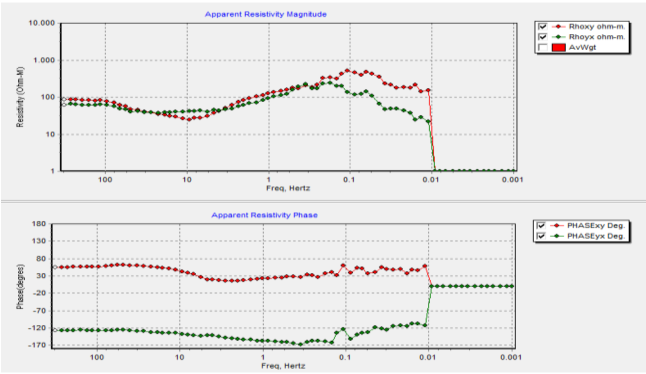

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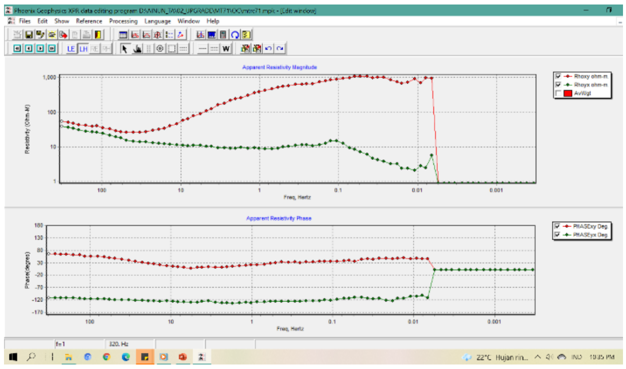

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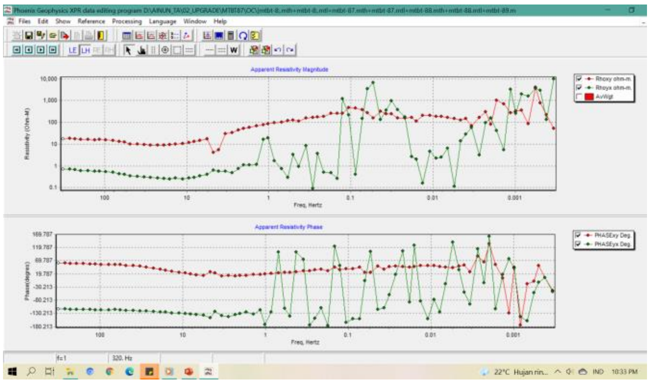

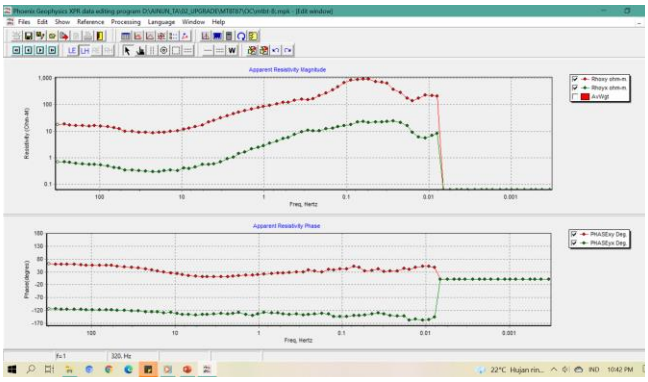

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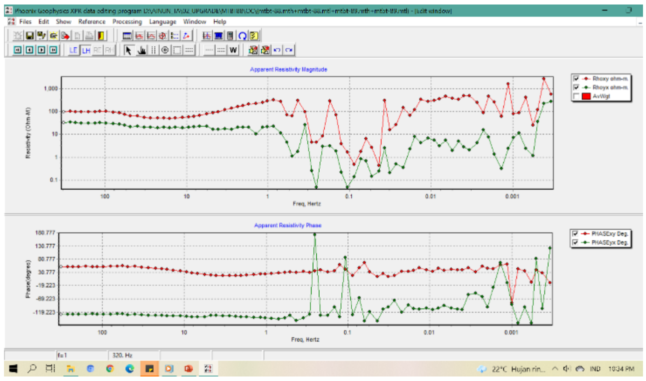

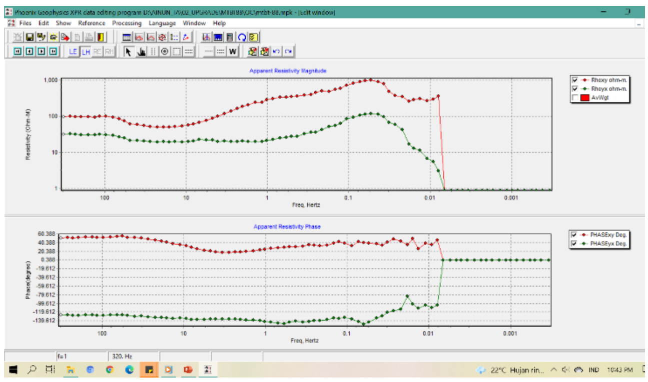

LAMPIRAN 2

Hasil Model 1D tiap titik pengukuran

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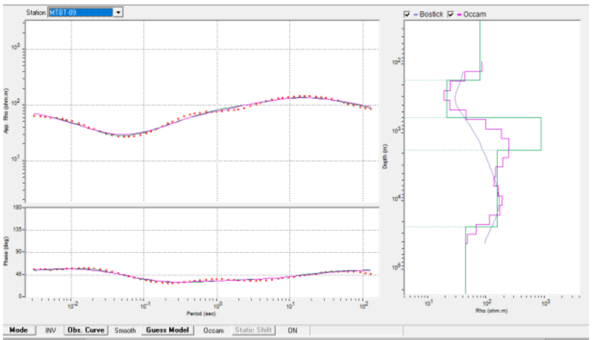

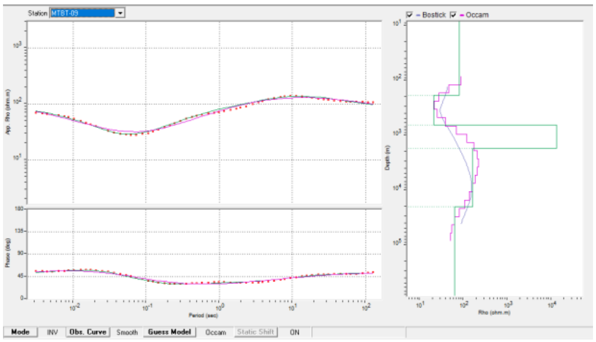

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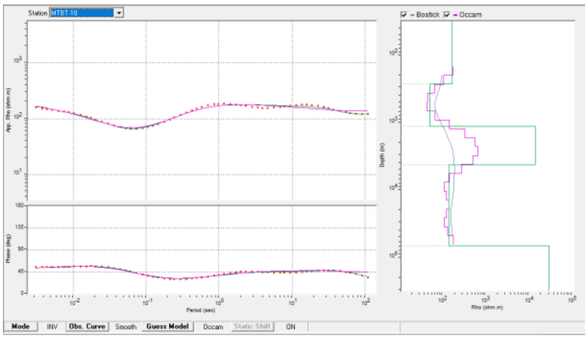

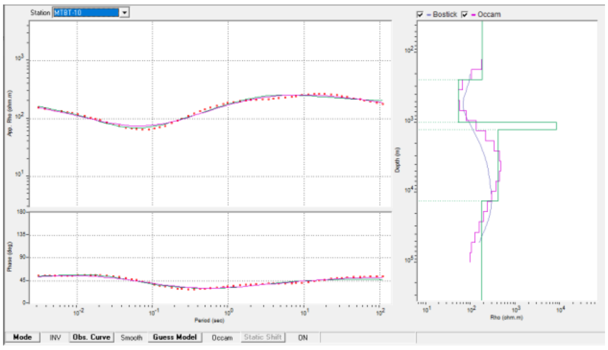

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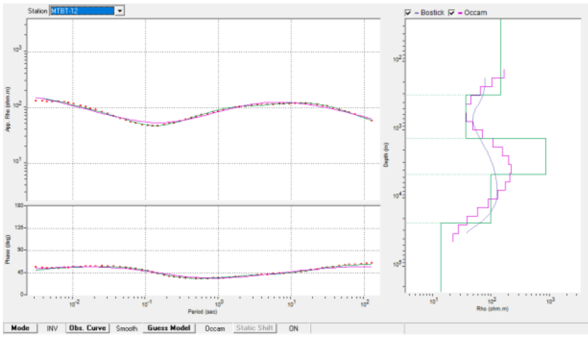

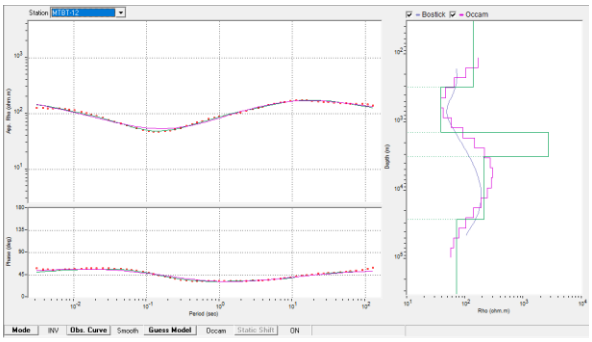

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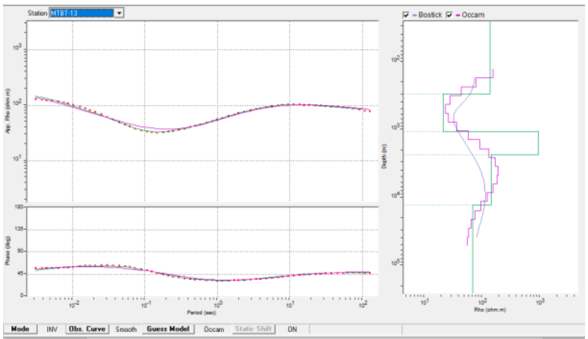

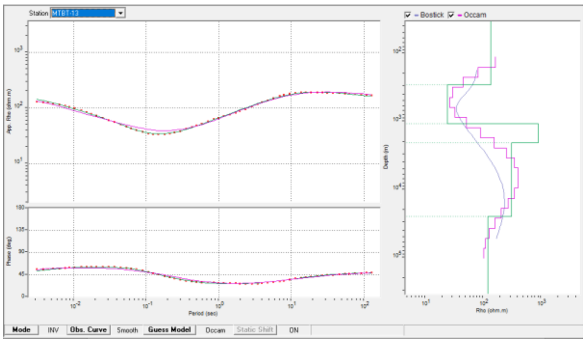

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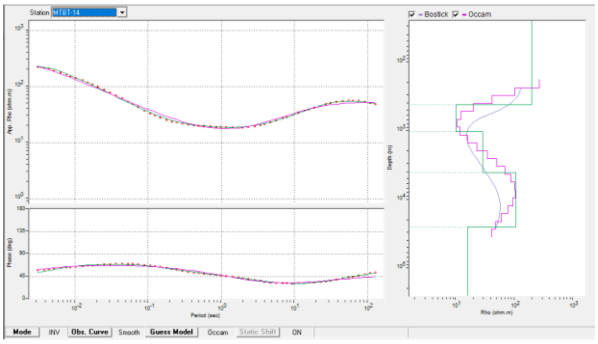
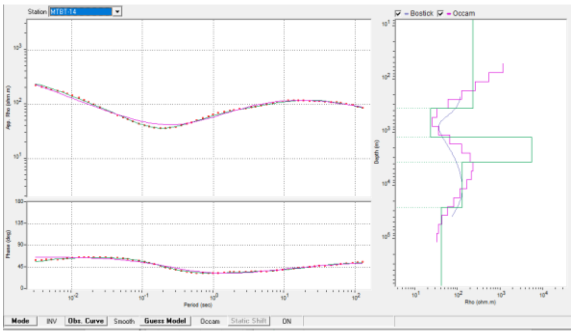

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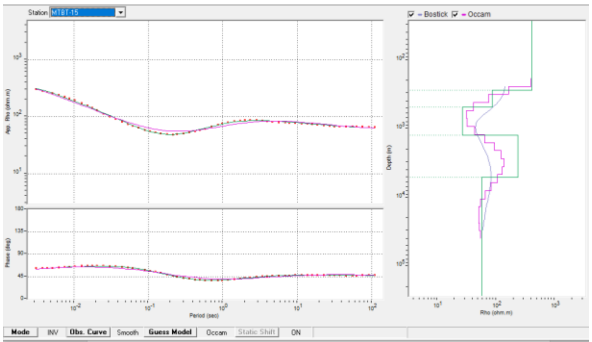
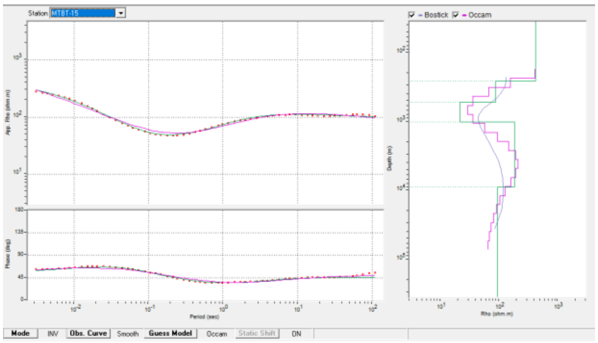

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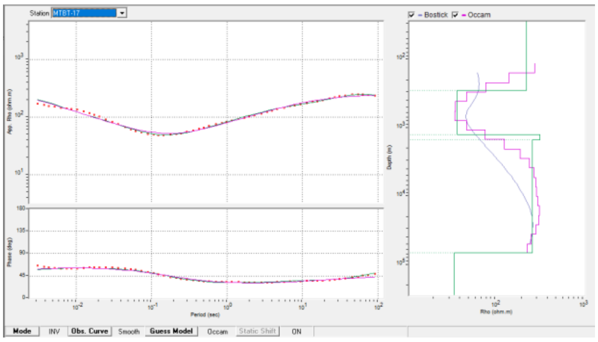
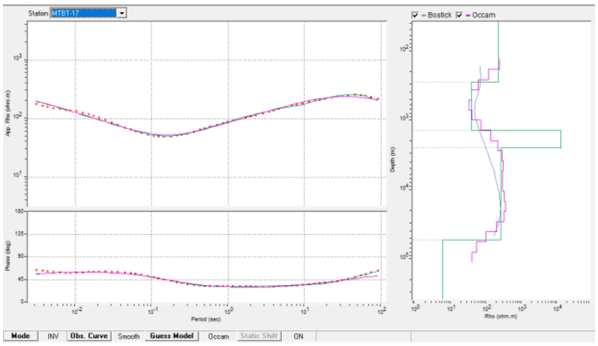

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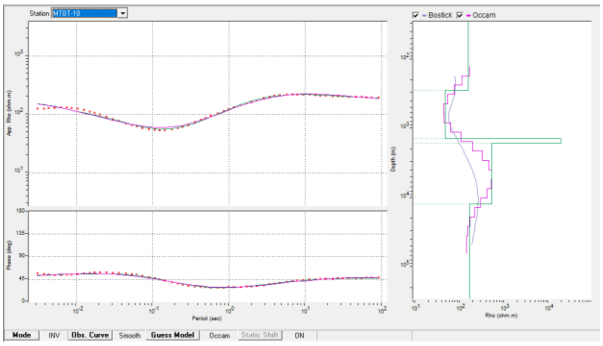
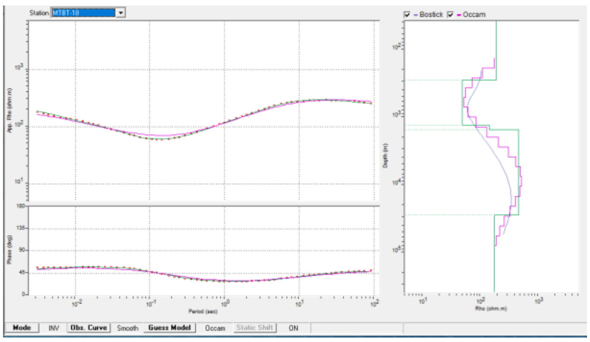

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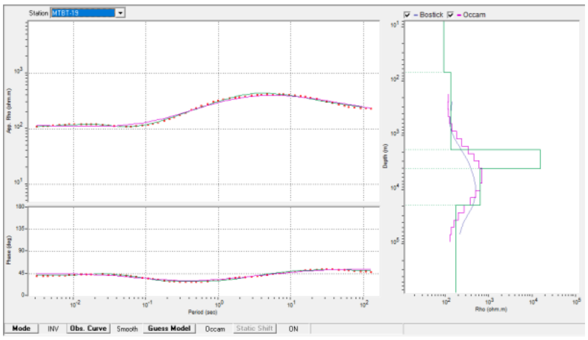

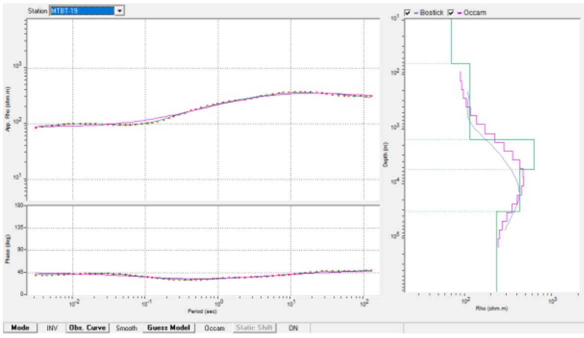

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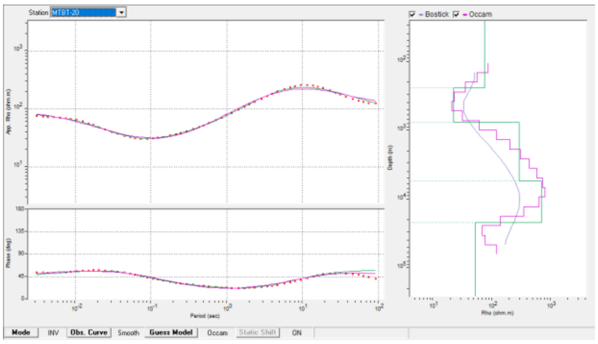

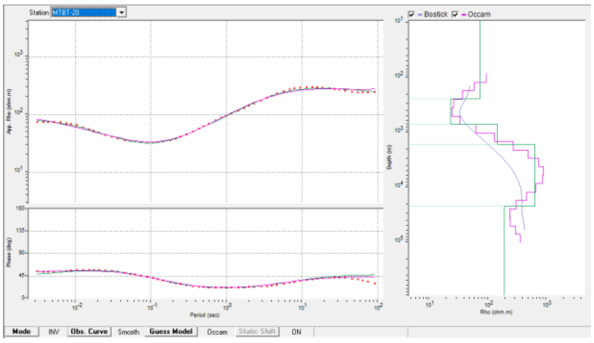

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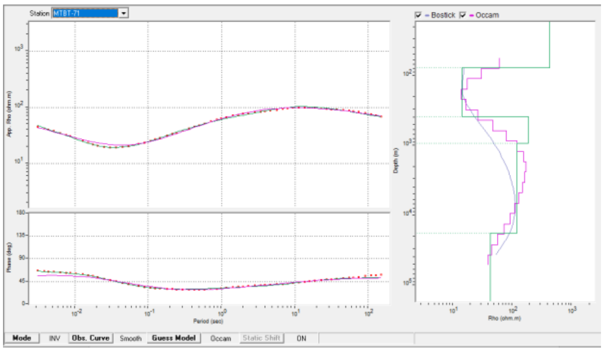

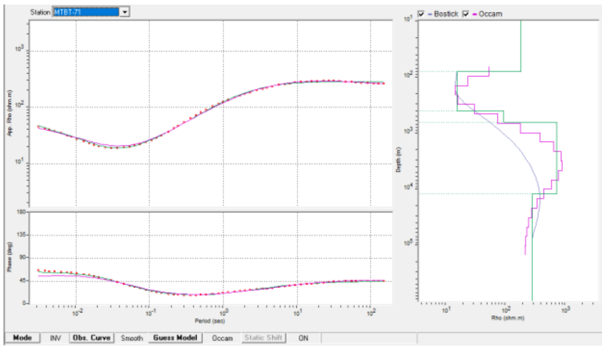

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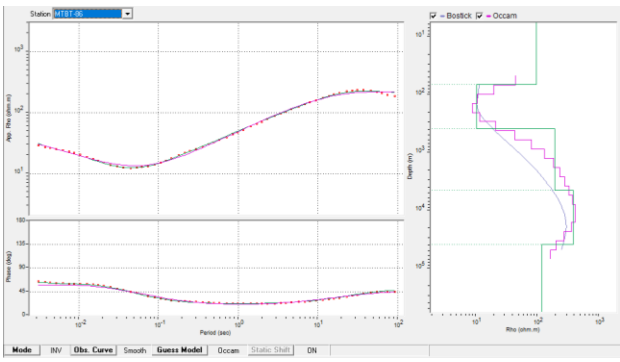

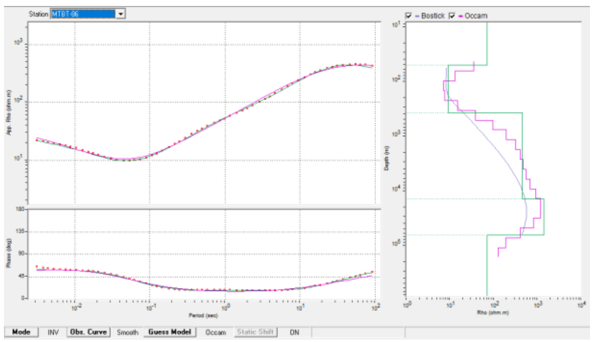

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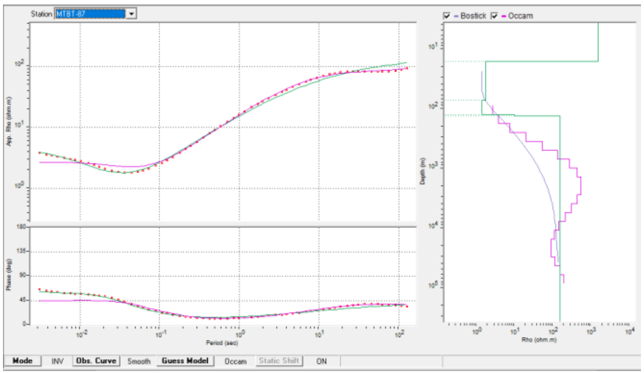

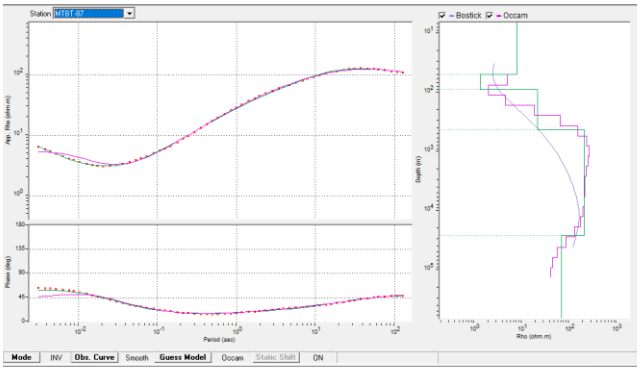

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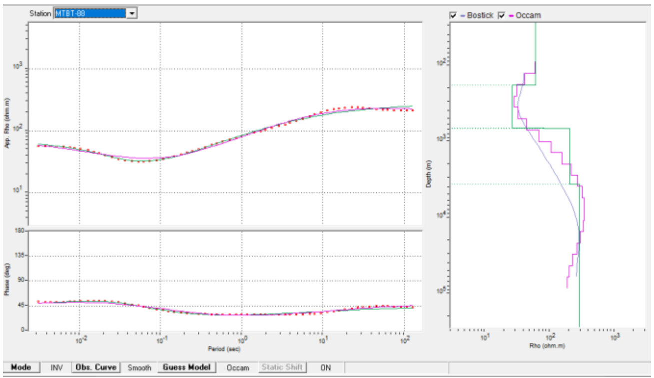

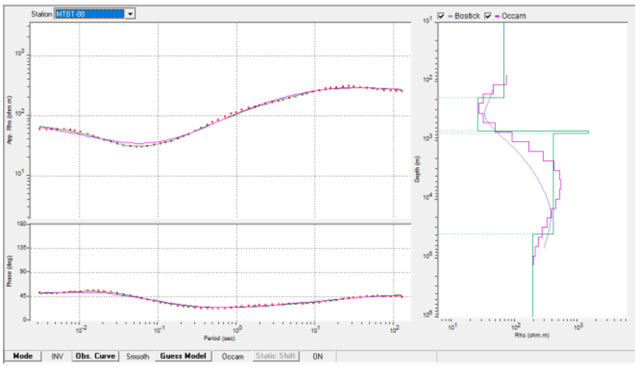

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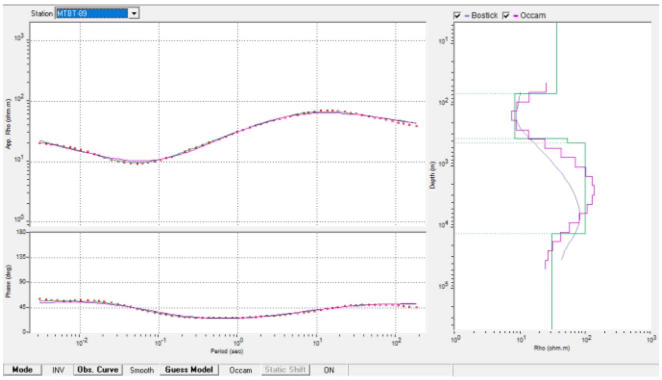

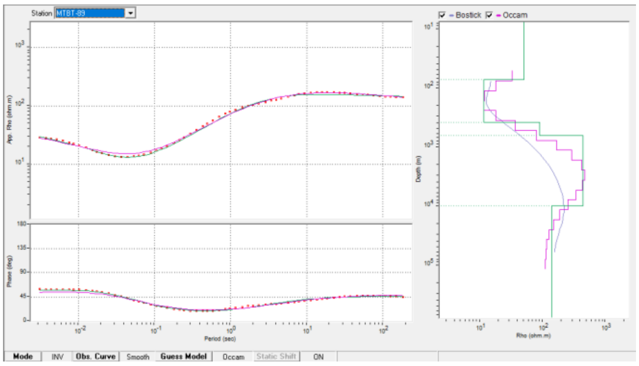

Lampiran 3

Hasil statik shift

L1

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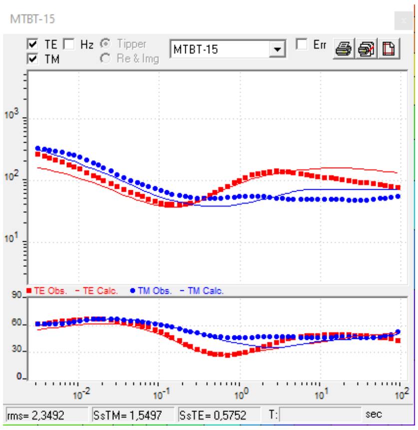

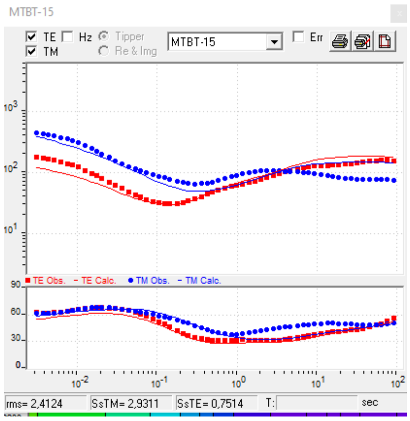

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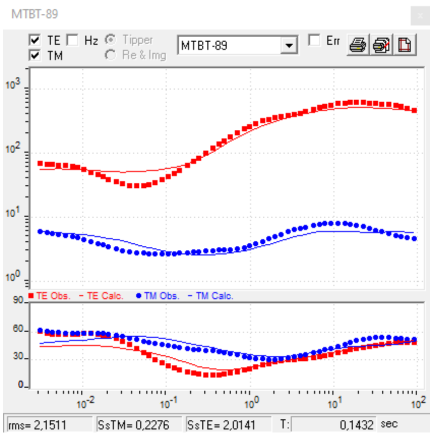

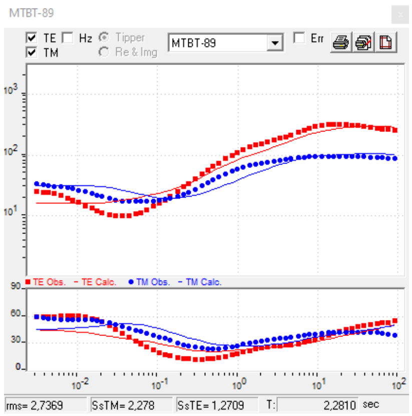

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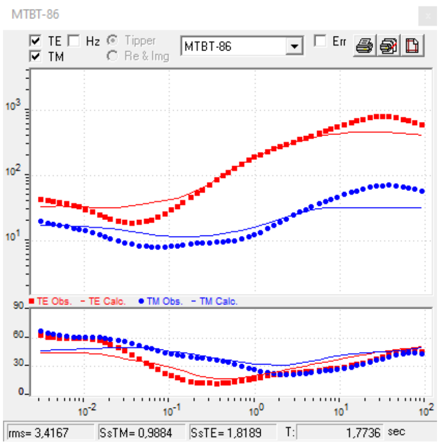

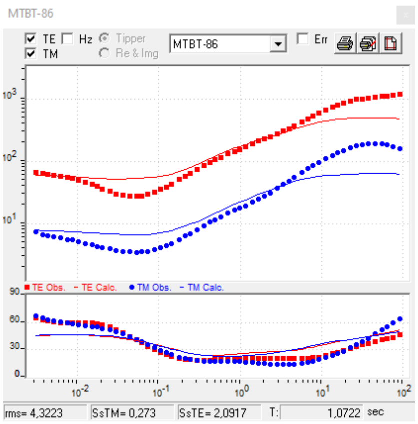

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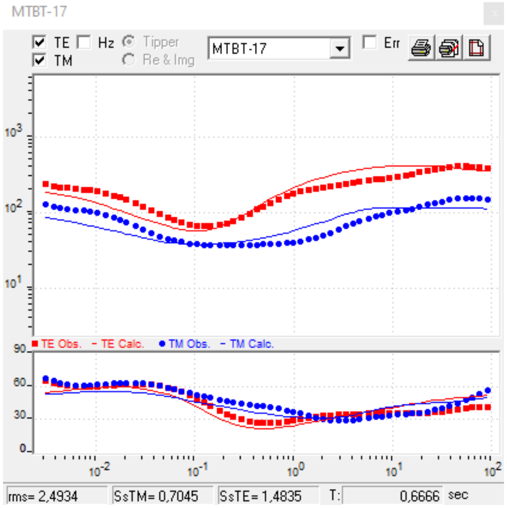

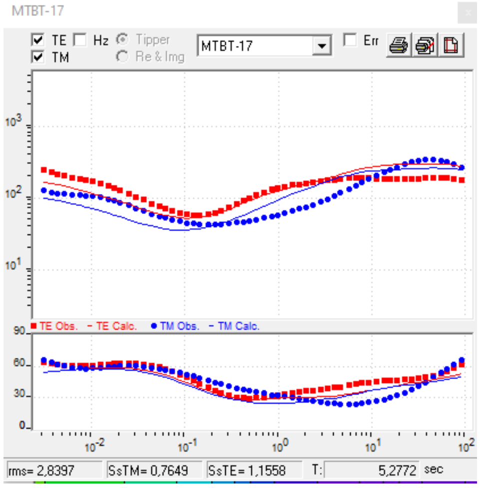

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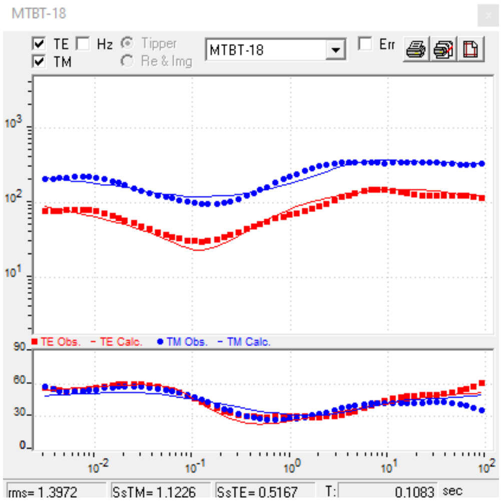

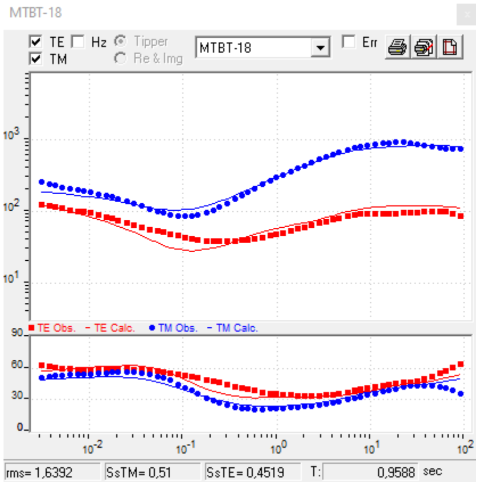

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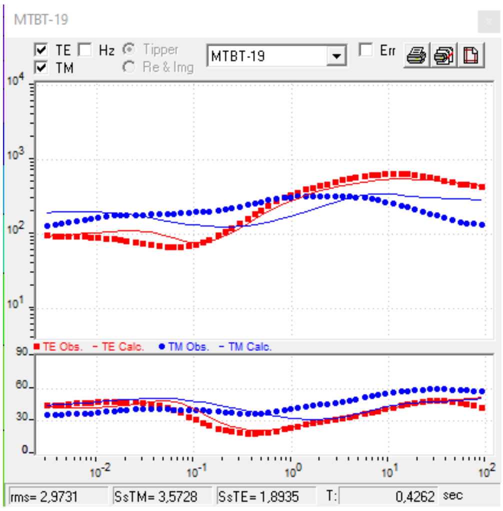

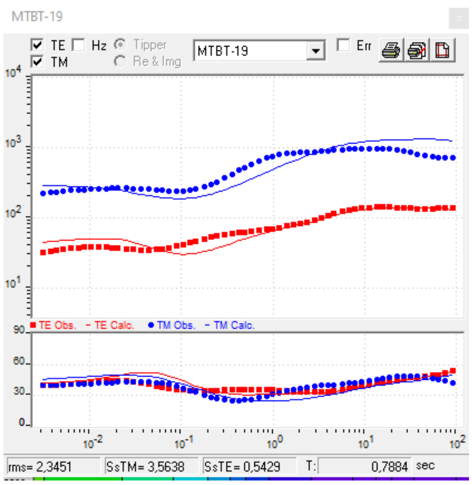

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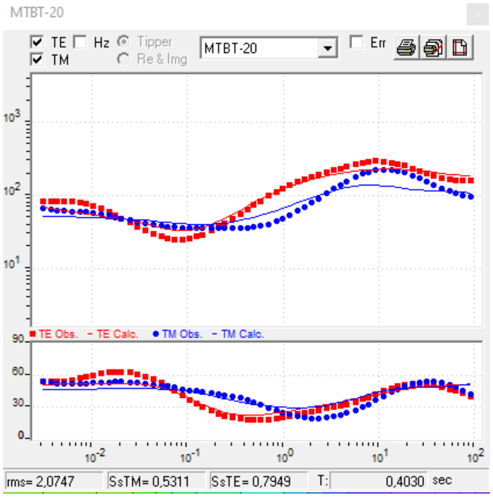

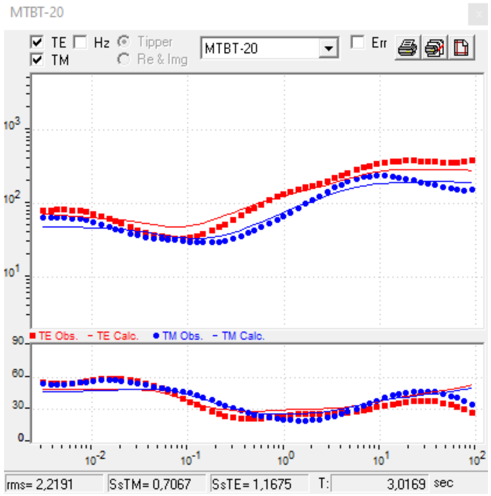

L2

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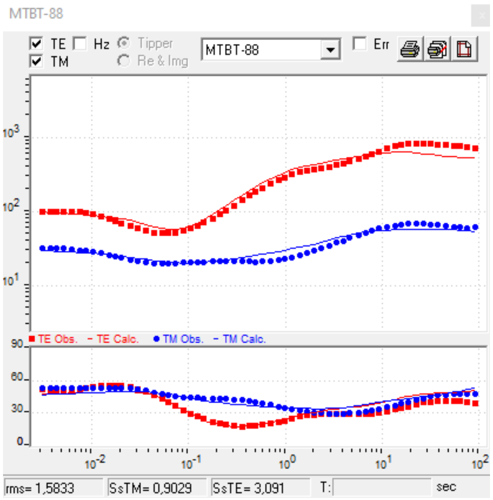

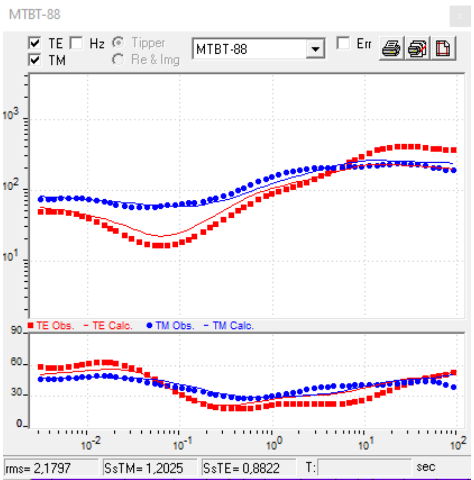

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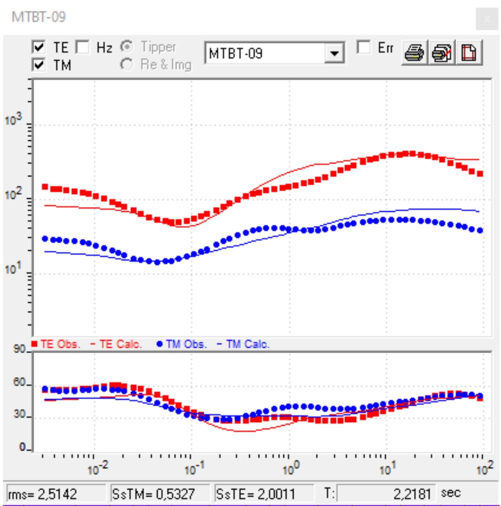

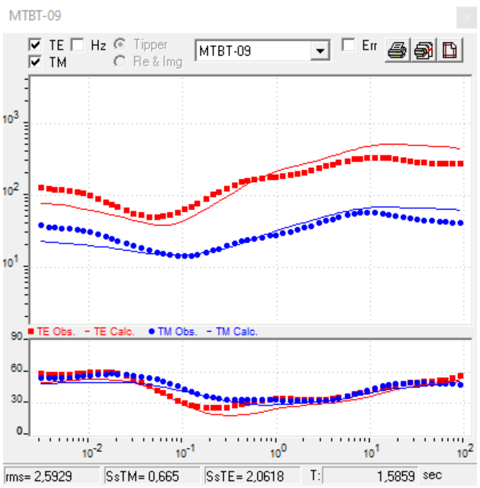

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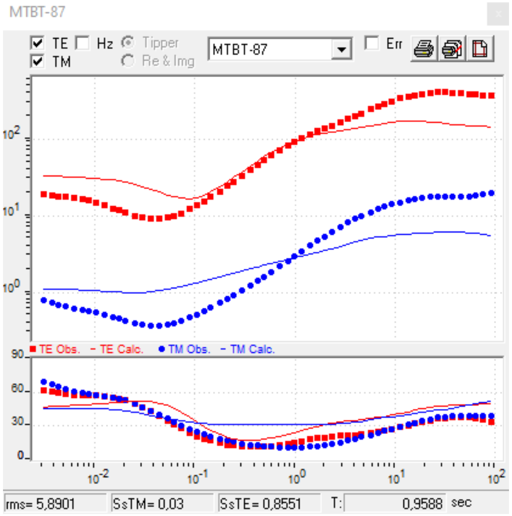

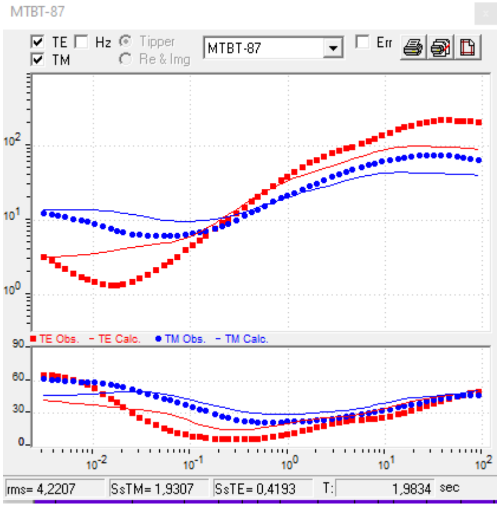

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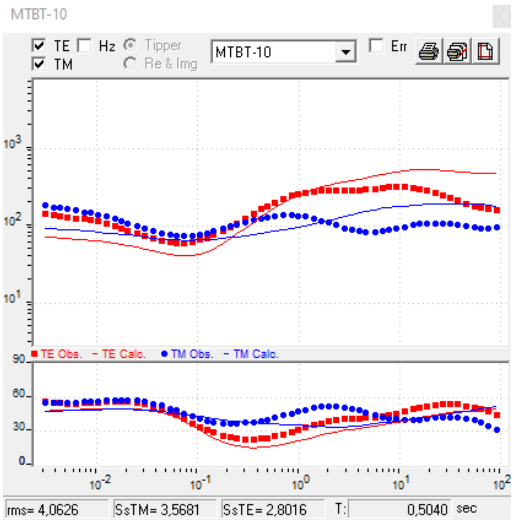

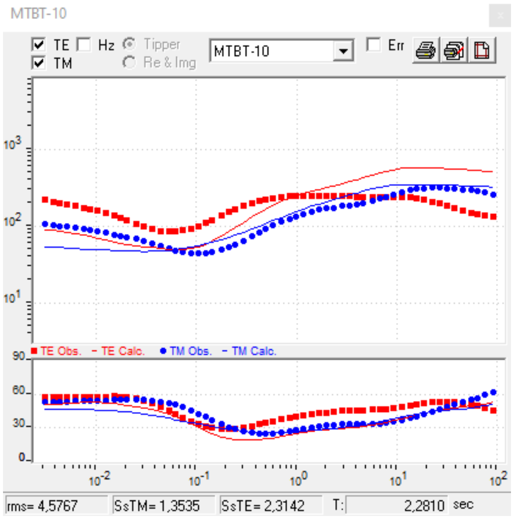

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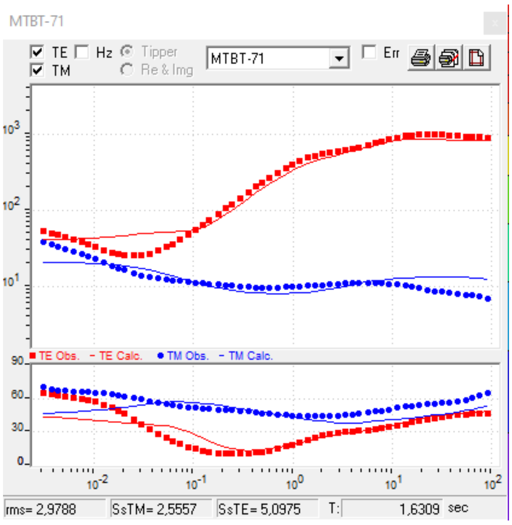

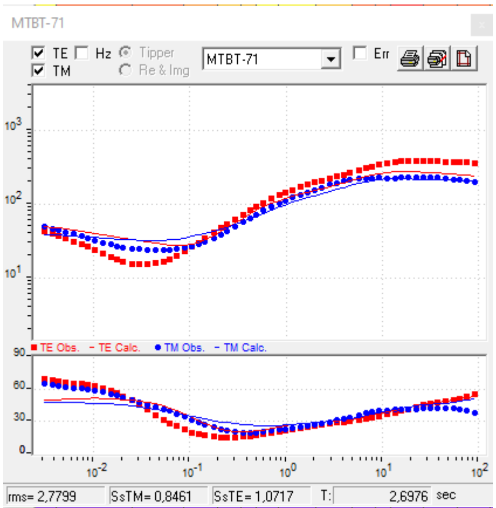

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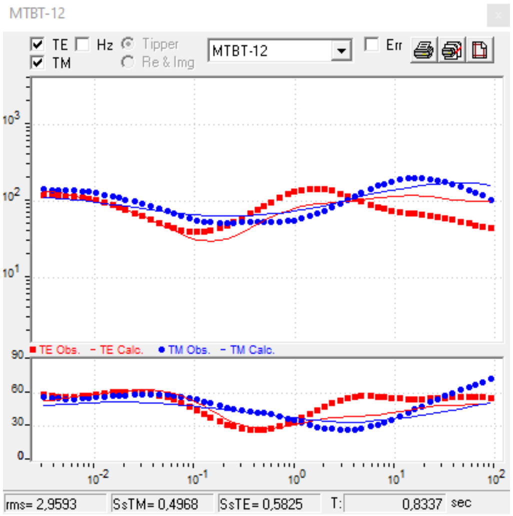

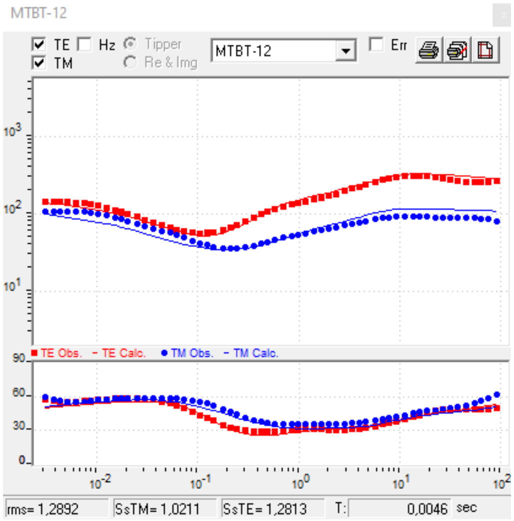

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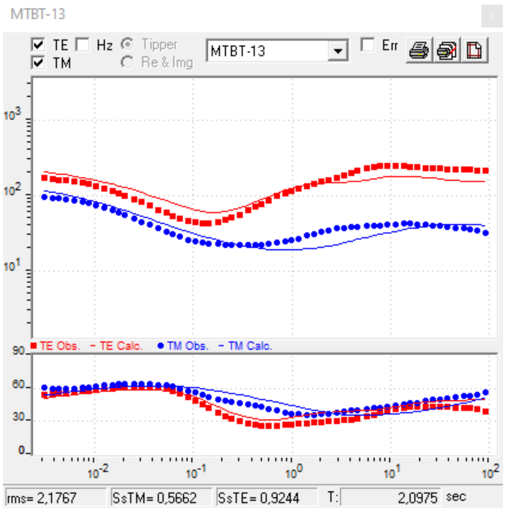

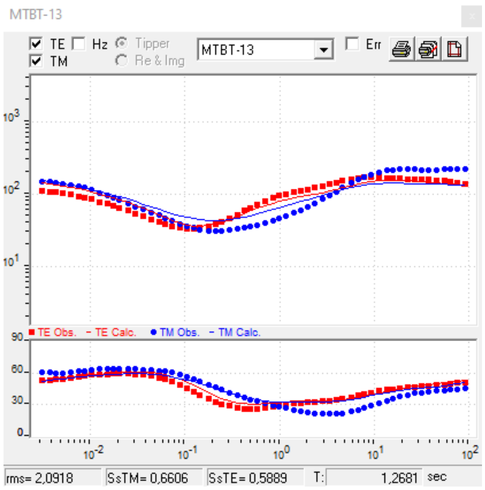

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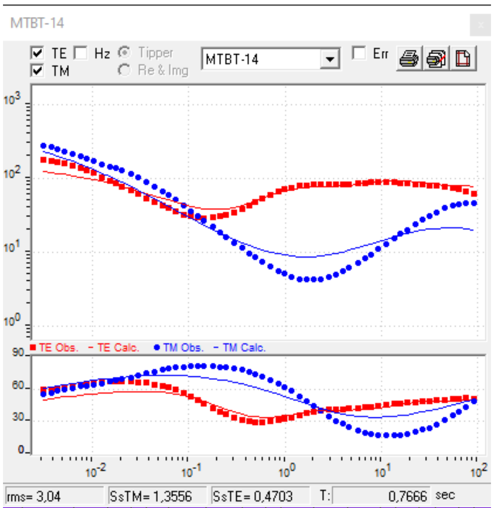

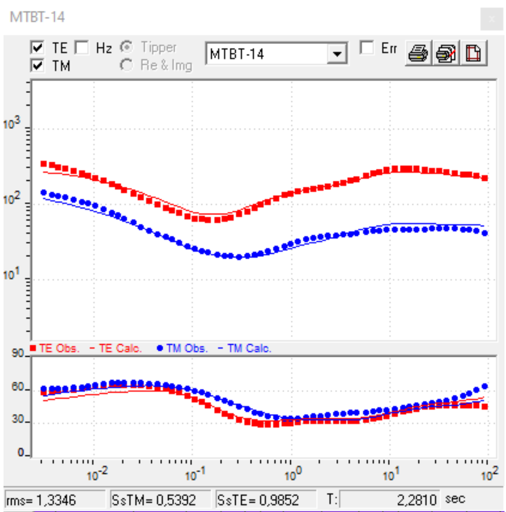

LAMPIRAN PERSAMAAN MAXWELL

Persamaan Maxwell yang digunakan dalam Metode Magnetotelurik:

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad (1)$$

$$\nabla \times H = \frac{\partial D}{\partial t} + J \quad (2)$$

$$\nabla . D = \rho \quad (3)$$

$$\nabla . B = 0 \quad (4)$$

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

$$D = \varepsilon E$$

$$B = \mu H$$

$$J = \sigma E$$

Jadi,

$$\nabla \times E = -\mu \frac{\partial H}{\partial t} \quad (5)$$

$$\nabla \times H = \varepsilon \frac{\partial E}{\partial t} + \sigma E \quad (6)$$

$$\nabla . D = \frac{\rho}{\varepsilon} \quad (7)$$

$$\nabla . H = 0 \quad (8)$$

Dari persamaan 5 dan 6 diperoleh:

Persamaan 5:

$$\nabla \times (\nabla \times E) = \nabla \times \left(-\mu \frac{\partial H}{\partial t}\right)$$

$$= -\mu \frac{\partial}{\partial t} (\nabla \times H)$$

$$= -\mu \frac{\partial}{\partial t} \left(\varepsilon \frac{\partial E}{\partial t} + \sigma E\right)$$

$$\nabla \times (\nabla \times E) = -\mu \frac{\partial}{\partial t} \left(\frac{\partial^2 E}{\partial t^2} + -\mu\sigma \frac{\partial E}{\partial t}\right)$$

$$\nabla \times (\nabla \times E) + \mu \frac{\partial}{\partial t} \left(\frac{\partial^2 E}{\partial t^2} + \mu\sigma \frac{\partial E}{\partial t}\right) = 0 \quad (9)$$

Persamaan 6

$$\nabla \times (\nabla \times H) = \nabla \times \left(\varepsilon \frac{\partial E}{\partial t} + \sigma E\right)$$

$$= \varepsilon \frac{\partial}{\partial t} (\nabla \times E) + \sigma (\nabla \times E)$$

$$= \varepsilon \frac{\partial}{\partial t} \left(-\mu \frac{\partial H}{\partial t}\right) + \sigma \left(-\mu \frac{\partial H}{\partial t}\right)$$

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

$$\nabla \times \nabla \times H + \varepsilon\mu \frac{\partial^2 H}{\partial t^2} + \sigma\mu \frac{\partial H}{\partial t} = 0 \qquad (10)$$

Diketahui bahwa $\nabla \times \nabla \times A = \nabla\nabla . A - \nabla^2 A$

karena $\nabla . E = 0$ dan $\nabla . H = 0$, maka:

- Dari persamaan 9

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

$$\nabla(\nabla . E) - \nabla^2 E + \varepsilon\mu \frac{\partial^2 E}{\partial t^2} + \sigma\mu \frac{\partial E}{\partial t} = 0$$

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

$$\nabla^2 E - \varepsilon\mu \frac{\partial^2 E}{\partial t^2} - \sigma\mu \frac{\partial E}{\partial t} = 0 \qquad (11)$$

- Dari persamaan 10

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

$$\nabla(\nabla . H) - \nabla^2 H + \varepsilon\mu \frac{\partial^2 H}{\partial t^2} + \sigma\mu \frac{\partial H}{\partial t} = 0$$

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

$$\nabla^2 H - \varepsilon\mu \frac{\partial^2 H}{\partial t^2} - \sigma\mu \frac{\partial H}{\partial t} = 0 \qquad (12)$$

- Dari persamaan (11)

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

$$\nabla^2 E - \varepsilon\mu \frac{\partial^2 (E_{oe}{}^{i(\omega t - kz)})}{\partial t^2} - \sigma\mu \frac{\partial (E_{oe}{}^{i(\omega t - kz)})}{\partial t} = 0$$

$$\nabla^2 E - i\omega\varepsilon\mu \frac{\partial^2}{\partial t^2}(E_o e^{i\omega t} e^{kz}) - \omega\sigma\mu \frac{\partial}{\partial t}(E_0 e^{i\omega t} e^{-ikz}) = 0$$

$$\nabla^2 E - \omega^2\varepsilon\mu\,(E_o e^{i\omega t} e^{kz}) - i\omega\sigma\mu(\mathrm{E}_0\, e^{i\omega t} e^{-ikz}) = 0$$

$$\nabla^2 E - \omega^2\varepsilon\mu\,(E) - i\omega\sigma\mu(E) = 0$$

$$\nabla^2 E - (\omega^2\varepsilon\mu - i\omega\sigma\mu)E = 0 \qquad (13)$$

- Dari persamaan (12)

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

$$\nabla^2 H - \varepsilon\mu \frac{\partial^2 (H_{oe}{}^{i(\omega t - kz)})}{\partial t^2} - \sigma\mu \frac{\partial (H_{oe}{}^{i(\omega t - kz)})}{\partial t} = 0$$

$$\nabla^2 H - \omega^2\varepsilon\mu\,(H) - i\omega\sigma\mu\,(H) = 0$$

$$\nabla^2 H - (\omega^2\varepsilon\mu - i\omega\sigma\mu)\,H = 0 \qquad (14)$$

Perambatan dalam medium bumi (material bumi memiliki nilai konduktifitas 10^{-3} S/m ≤ $\sigma \leq 10^3$ S/m, dan nilai permivitas ε dianggap sama dengan ε_0) dan gelombang yang merambat memiliki frekuensi rendah (f < 10 kHz) maka $\sigma >> \varepsilon\omega$. sehingga persamaan (13) dan (14) menjadi:

$$\nabla^2 E - i\omega\sigma\mu E = 0 \qquad (15)$$

$$\nabla^2 H - i\omega\sigma\mu\, H = 0 \tag{16}$$

Atau dalam bentuk lain:

$$\nabla^2 E + K^2 E = 0 \tag{17}$$

$$\nabla^2 H + K^2 H = 0 \tag{18}$$

Dimana k merupakan bilangan gelombang.

<u>NILAI K diperoleh dari:</u>

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

$$\frac{\partial^2 \left(E_0 e^{ikz} e^{\,i\omega t}\right)}{\partial z^2} = \mu\sigma \frac{\partial (E_0 e^{ikz} e^{\,i\omega t})}{\partial t} + \mu\varepsilon \frac{\partial^2 (E_0 e^{ikz} e^{\,i\omega t})}{\partial t^2}$$

$$-i\mathrm{k} \frac{\partial \left(E_0 e^{ikz} e^{\,i\omega t}\right)}{\partial z} = i\omega\mu\sigma\left(E_0 e^{ikz} e^{\,i\omega t}\right) + i\omega\mu\varepsilon \frac{\partial \left(E_0 e^{ikz} e^{\,i\omega t}\right)}{\partial t}$$

$$\mathrm{k}^2 E_0 e^{ikz} e^{\,i\omega t} = i\omega\mu\sigma\left(E_0 e^{ikz} e^{\,i\omega t}\right) + \mu\varepsilon\left(-\omega^2 E_0 e^{ikz} e^{\,i\omega t}\right)$$

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

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

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

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

$$\mathrm{k}^2 = i\omega\mu\sigma$$

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

SKIN DEPTH

Prinsip bahwa medan *E* dan *H* meluruh seiring dengan bertambahnya kedalaman z, amplitudo medan *E* dan *H* dalam medium bumi akan meluruh sebesar faktor 1/*e* pada jarak δ, disebut *skin depth.*

$$\delta = \frac{1}{Re\,(k)}$$

Dimana:

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

$$k = \sqrt{-1}\sqrt{\mu\omega\sigma}$$

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

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

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

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

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

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

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

$$1 + i - 1 = i$$

$$i = i$$

Sehingga:

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

$$= \sqrt{\frac{2\rho}{\mu\omega}}$$

$$= \sqrt{\frac{2\rho}{4\pi.10^{-7}.2\pi f}}$$

$$= \sqrt{\frac{2\rho T}{8\pi.10^{-7}}}$$

$$= \sqrt{\frac{\rho T}{4\pi.10^{-7}}}$$

$$= \sqrt{\frac{\rho T}{4\pi.10^{-7}}}$$

$= \frac{1}{2\pi}\sqrt{\frac{\rho T}{10^{-7}}}$

$= \frac{1}{2\pi}\sqrt{\frac{\rho T}{10^{-7}}}$

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

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

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

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

$= 503\sqrt{\frac{\rho}{f}}$ → satuan meter

<u>IMPEDANSI</u>

Berdasarkan arah induksi:

$Z_{xy} = \frac{E_x}{H_y}$ dan $Z_{xy} = \frac{E_y}{H_x}$

Untuk struktur yang bervariasi terhadap lateral maka nilai impedansinya yaitu

(dalam bentuk linear)

$E_x = Z_{xx}H_x + Z_{xy}H_y$

Dan.

$E_y = Z_{yx}H_x + Z_{yy}H_y$

Resistivitas semu diperoleh dari:

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

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

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

$$i\omega\mu\sigma = \frac{i\omega\mu.i\omega\mu}{Z_i^{\,2}}$$

$$Z_i^{\,2} = \frac{i\omega\mu.i\omega\mu}{i\omega\mu\sigma}$$

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

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

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

$$\rho = \frac{1}{i\omega\mu}\left|Z_i^{\,2}\right|$$

Dan untuk phase adalah,

$$\phi = tan^{-1}\left(\frac{im\,Z_i}{ReZ_i}\right)$$

STRUKTUR RESISTIVITAS 2 DIMENSI

- **MODE TE (TRANSVERSE ELECTRIC)**

Komponen yang terdapat pada mode TE yaitu, E_x, H_y dan H_z. Dengan menggunakan persamaan Maxwell berikut yaitu:

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

Maka,

$$\left(\frac{\partial}{\partial_x}i + \frac{\partial}{\partial_y}j + \frac{\partial}{\partial_z}k\right) \times \left(E_x i + E_y j + E_z k\right) = -\mu\frac{\partial H}{\partial t}$$

$$\left(\frac{\partial E_z}{\partial_y} - \frac{\partial E_y}{\partial_z}\right)i + \left(\frac{\partial E_z}{\partial_x} - \frac{\partial E_x}{\partial_z}\right)j + \left(\frac{\partial E_y}{\partial_x} - \frac{\partial E_x}{\partial_y}\right)k = i\omega\mu H$$

$$\left(\frac{\partial E_z}{\partial_y} - \frac{\partial E_y}{\partial_z}\right)i + \left(\frac{\partial E_z}{\partial_x} - \frac{\partial E_x}{\partial_z}\right)j + \left(\frac{\partial E_y}{\partial_x} - \frac{\partial E_x}{\partial_y}\right)k = i\omega\mu(H_x i + H_y j + H_z k)$$

Karena hanya terdapat komponen E_x, H_y dan H_z, maka dapat disederhanakan menjadi,

$$\frac{\partial E_x}{\partial_z}j - \frac{\partial E_x}{\partial_y}k = i\omega\mu\left(H_y j + H_z k\right)$$

$H_y = \frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_z}$

$H_z = -\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y}$

Dari persamaan Maxwell berikut diperoleh:

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

cat: nilai ε diabaikan karena memiliki nilai yang sangat kecil

Sehingga didapatkan

$\left(\frac{\partial}{\partial_x} i + \frac{\partial}{\partial_y} j + \frac{\partial}{\partial_z} k\right) \times \left(H_x i + H_y j + H_z k\right) = \sigma E$

$\left(\frac{\partial H_z}{\partial_y} - \frac{\partial H_y}{\partial z}\right) i + \left(\frac{\partial H_x}{\partial_z} - \frac{\partial H_z}{\partial x}\right) j + \left(\frac{\partial H_y}{\partial_x} - \frac{\partial H_x}{\partial y}\right) k = \sigma \left(E_x i + E_y j + E_z k\right)$

$\left[\frac{\partial}{\partial_y}\left(-\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y}\right) - \frac{\partial}{\partial_y}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_Z}\right)\right] i + \left[-\frac{\partial}{\partial_x}\left(-\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y}\right)\right] j + \left[\frac{\partial}{\partial_y}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_Z}\right)\right] k = \sigma E_x i$

$-\left(\frac{\partial}{\partial_z} i - \frac{\partial}{\partial_x} k\right)\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_Z} - \left(\frac{\partial}{\partial_y} i - \frac{\partial}{\partial_x} j\right)\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y} = \sigma E_x i$

$\frac{\partial}{\partial_z}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_Z}\right) + \frac{\partial}{\partial_y}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y}\right) = \sigma E_x$

$\frac{\partial}{\partial_z}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_Z}\right) + \frac{\partial}{\partial_y}\left(\frac{1}{i\mu\omega}\frac{\partial E_x}{\partial_y}\right) - \sigma E_x = 0$

- **MODE TM (TRANSVERSE MAGNETIC)**

Komponen medan yang terdapat pada modus TM yaitu, H_x dan E_y . dengan menggunakan persamaan:

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

$\left(\frac{\partial}{\partial_x} i + \frac{\partial}{\partial_y} j + \frac{\partial}{\partial_z} k\right) \times \left(H_x i + H_y j + H_z k\right) = \sigma E$

$\left(\frac{\partial H_z}{\partial_y} - \frac{\partial H_y}{\partial z}\right) i + \left(\frac{\partial H_x}{\partial_z} - \frac{\partial H_z}{\partial x}\right) j + \left(\frac{\partial H_y}{\partial_x} - \frac{\partial H_x}{\partial y}\right) k = \sigma \left(E_x i + E_y j + E_z k\right)$

Karena hanya komponen H_x dan E_y yang terdapat pada mode TM, maka:

$$\frac{\partial H_x}{\partial_z} j - \frac{\partial H_x}{\partial_y} k = \sigma E_y j$$

Kemudian dari persamaan maxwell berikut:

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

$$\left(\frac{\partial E_z}{\partial_y} - \frac{\partial E_y}{\partial z}\right) i + \left(\frac{\partial E_x}{\partial_z} - \frac{\partial E_z}{\partial x}\right) j + \left(\frac{\partial E_y}{\partial_x} - \frac{\partial E_x}{\partial y}\right) k = i\mu\omega \left(H_x i + H_y j + H_z k\right)$$

Sehingga didapatkan:

$$-\left(\frac{\partial}{\partial_z} i - \frac{\partial}{\partial_x} k\right) \frac{1}{\sigma} \frac{\partial H_x}{\partial_Z} - \left(\frac{\partial}{\partial_y} i - \frac{\partial}{\partial_x} j\right) \frac{1}{\sigma} \frac{\partial H_x}{\partial_y} = i\mu\omega H_x i$$

$$\frac{\partial}{\partial_z}\left(\frac{1}{\sigma} \frac{\partial H_x}{\partial_Z}\right) + \frac{\partial}{\partial_y}\left(\frac{1}{\sigma} \frac{\partial H_x}{\partial_y}\right) = i\mu\omega H_x$$

$$\frac{\partial}{\partial_z}\left(\frac{1}{\sigma} \frac{\partial H_x}{\partial_Z}\right) + \frac{\partial}{\partial_y}\left(\frac{1}{\sigma} \frac{\partial H_x}{\partial_y}\right) - i\mu\omega H_x = 0$$

$$E_x = \frac{1}{\sigma} \frac{\partial H_x}{\partial_y}$$

$$H_z = \frac{1}{\sigma} \frac{\partial H_x}{\partial_Z}$$