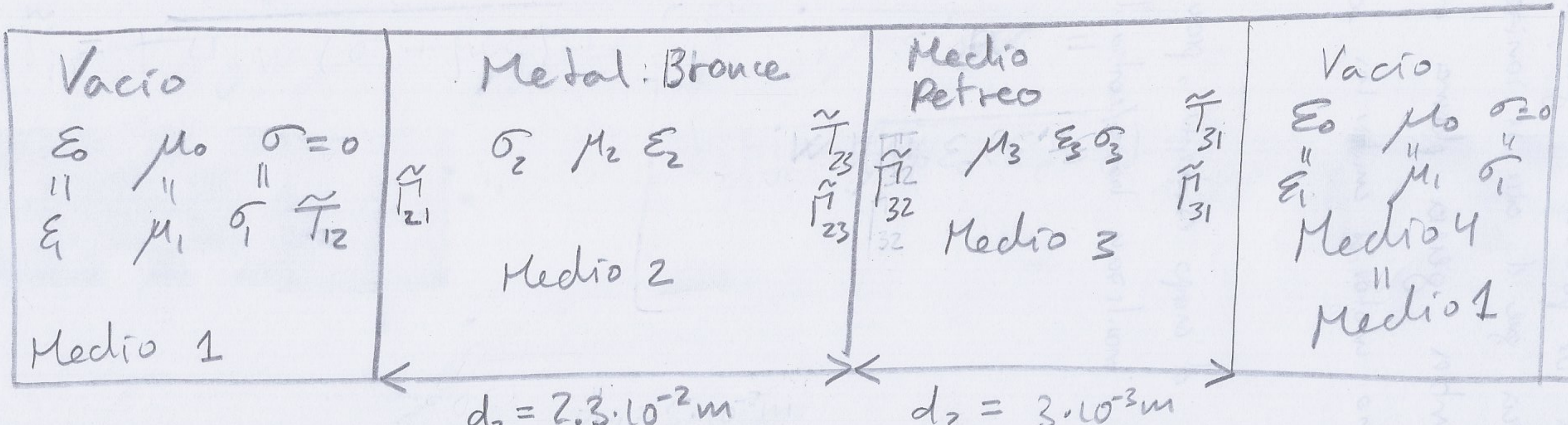
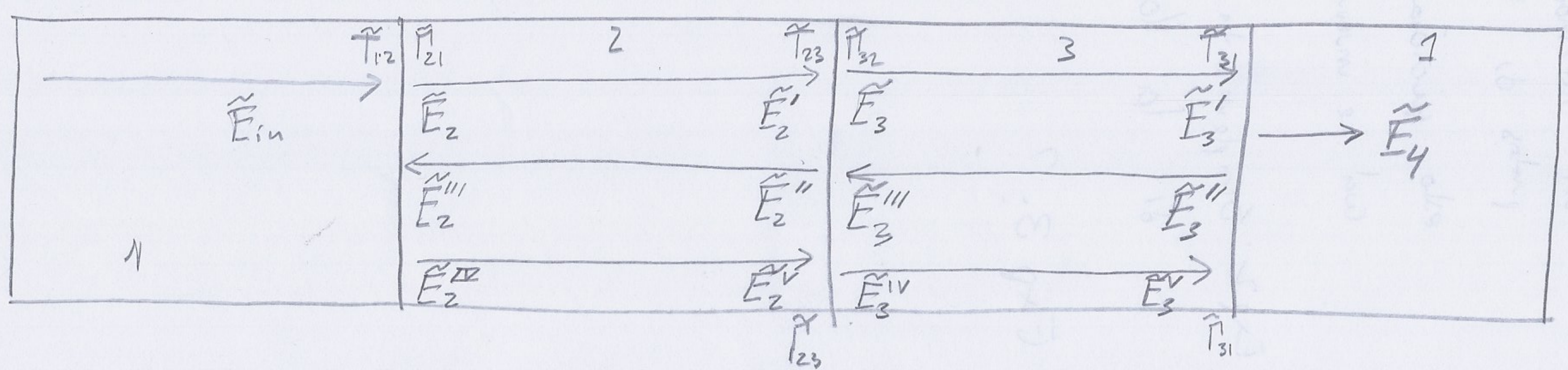
Problema 2

1> Comenzamos calculando los parámetros. No calculamos la tangente de pérdidas porque no vamos a hacer aproximaciones. $\nu = 6 \cdot 10^{17}\ Hz$

$$w = 2\pi\nu = 3.76991 \cdot 10^{18}\ \frac{rad}{s}$$



¿Qué parámetros necesitamos?



$$\tilde{E}_2 = \tilde{E}_{in}\tilde{T}_{12} \; ; \; \tilde{E}_2' = \tilde{E}_2 e^{-\alpha_2 d_2} = \tilde{E}_{in}\tilde{T}_{12} e^{-\alpha_2 d_2} \; ; \; \tilde{E}_2'' = \tilde{E}_2'\tilde{\Gamma}_{23} = \tilde{E}_{in}\tilde{T}_{12}\tilde{\Gamma}_{23} e^{-\alpha_2 d_2} \quad \mathrm{II}$$

$$\tilde{E}_2''' = \underbrace{\tilde{E}_{in}\tilde{T}_{12}\tilde{\Gamma}_{23} e^{-\alpha_2 d_2}}_{\tilde{E}_2''} e^{\alpha_2(-d_2)} \; ; \; \tilde{E}_2^{IV} = \tilde{E}_2'''\tilde{\Gamma}_{21} = \tilde{E}_{in}\tilde{T}_{12}\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-\alpha_2 d_2} e^{\alpha_2(-d_2)}$$

$$\tilde{E}_2^{V} = \tilde{E}_2^{IV} e^{-\alpha_2 d_2} = \tilde{E}_{in}\tilde{T}_{12}\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-\alpha_2 d_2} e^{\alpha_2(-d_2)} e^{-\alpha_2 d_2} = \tilde{E}_{in}\tilde{T}_{12}\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-3\alpha_2 d_2}$$

$$\tilde{E}_3 = (\tilde{E}_2' + \tilde{E}_2^{V})\tilde{T}_{23} = \tilde{E}_{in} e^{-\alpha_2 d_2}\tilde{T}_{12}\left(1 + \tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-2\alpha_2 d_2}\right)\tilde{T}_{23}$$

$$\tilde{E}_3' = \tilde{E}_3 e^{-\alpha_3 d_3} \; ; \; \tilde{E}_3'' = \tilde{E}_3'\tilde{\Gamma}_{31} \; ; \; \tilde{E}_3''' = \tilde{E}_3'' e^{\alpha_3(-d_3)} \; ; \; \tilde{E}_3^{IV} = \tilde{\Gamma}_{32}\tilde{E}_3''' \; ; \; \tilde{E}_3^{V} = \tilde{E}_3^{IV} e^{-\alpha_3 d_3}$$

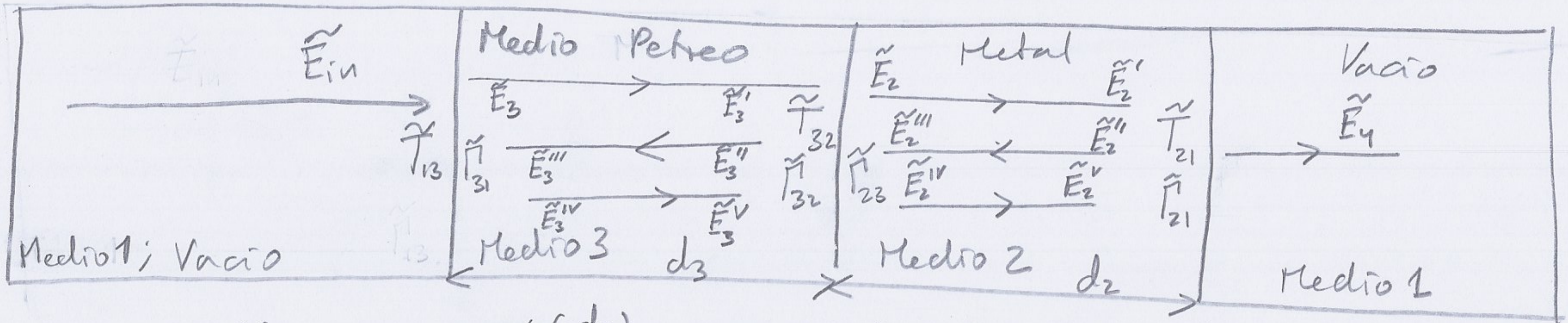
$$\tilde{E}_4 = (\tilde{E}^{V} + \tilde{E}_3')\tilde{T}_{31} = \Big(\underbrace{\tilde{E}_{in} e^{-\alpha_2 d_2}\tilde{T}_{12}\tilde{T}_{23}\left(1+\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-2\alpha_2 d_2}\right) e^{-\alpha_3 d_3}}_{\tilde{E}_3'}\Big)\left(1 + \tilde{\Gamma}_{31} e^{-2\alpha_3 d_3}\tilde{\Gamma}_{32}\right)\tilde{T}_{31} =$$

$$= \tilde{E}_{in}\tilde{T}_{31}\tilde{T}_{12}\tilde{T}_{23} e^{-\alpha_2 d_2 - \alpha_3 d_3}\left(1+\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-2\alpha_2 d_2}\right)\left(1+\tilde{\Gamma}_{31}\tilde{\Gamma}_{32} e^{-2\alpha_3 d_3}\right)$$

$$|\tilde{E}_{in}| \cdot \left|\tilde{T}_{31}\tilde{T}_{12}\tilde{T}_{23} e^{-\alpha_2 d_2 - \alpha_3 d_3}\left(1+\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-2\alpha_2 d_2}\right)\left(1+\tilde{\Gamma}_{31}\tilde{\Gamma}_{32} e^{-2\alpha_3 d_3}\right)\right| = E_{umbral} = 1\,\frac{\mu V}{m}$$

$$|\tilde{E}_{in}|_{\mathrm{ID}} = \frac{E_{umbral}}{\left|\tilde{T}_{31}\tilde{T}_{12}\tilde{T}_{23} e^{-\alpha_2 d_2 - \alpha_3 d_3}\left(1+\tilde{\Gamma}_{23}\tilde{\Gamma}_{21} e^{-2\alpha_2 d_2}\right)\left(1+\tilde{\Gamma}_{31}\tilde{\Gamma}_{32} e^{-2\alpha_3 d_3}\right)\right|}$$

$$|\vec{S}_{inAV}|_{\mathrm{ID}} = \frac{|\tilde{E}_{in}|^2_{\mathrm{ID}}}{2 \cdot \mathrm{Re}(\eta_1^*)}$$



$\tilde{E}_3 = \tilde{E}_{in}\tilde{T}_{13}$; $\tilde{E}_3' = \tilde{E}_3 e^{\alpha_3(-d_3)}$; $\tilde{E}_3'' = \tilde{E}_3'\tilde{\Gamma}_{32}$; $\tilde{E}_3''' = \tilde{E}_3'' e^{-\alpha_3 d_3}$; $\tilde{E}_3^{IV} = \tilde{\Gamma}_{31}\tilde{E}_3'''$;

$\tilde{E}_3^{V} = \tilde{E}_3^{IV} e^{\alpha_3(-d_3)}$; $\tilde{E}_2 = (\tilde{E}_3^{V} + \tilde{E}_3')\tilde{T}_{32}$;

$\tilde{E}_2 = \tilde{T}_{32}\tilde{E}_{in}\tilde{T}_{13}e^{-\alpha_3 d_3}\left(1 + \tilde{\Gamma}_{32}\tilde{\Gamma}_{31}e^{-2\alpha_3 d_3}\right)$ Vemos la simetría en los cálculos luego:

$$|\tilde{E}_{in}|_{DI} = \frac{E_{umbral}}{\left|\tilde{T}_{13}\tilde{T}_{32}\tilde{T}_{21}e^{-\alpha_2 d_2 - \alpha_3 d_3}\left(1+\tilde{\Gamma}_{32}\tilde{\Gamma}_{31}e^{-2\alpha_3 d_3}\right)\left(1+\tilde{\Gamma}_{23}\tilde{\Gamma}_{21}e^{-2\alpha_2 d_2}\right)\right|}$$

$$|\vec{S}_{in,AV}|_{DI} = \frac{|\tilde{E}_{in}|^2_{DI}}{2Re(\tilde{\eta}_1^*)}$$

Necesitamos $\tilde{T}_{12}, \tilde{T}_{23}, \tilde{T}_{31}, \tilde{T}_{13}, \tilde{T}_{32}, \tilde{T}_{21}$
$\tilde{\Gamma}_{21}, \tilde{\Gamma}_{23}, \tilde{\Gamma}_{32}, \tilde{\Gamma}_{31}, \alpha_2, \alpha_3$

obviamente $\left\{ \tilde{\gamma}_1, \tilde{\gamma}_2, \tilde{\gamma}_3, \tilde{\eta}_1, \tilde{\eta}_2, \tilde{\eta}_3 \right.$

Cálculo simplificado sin considerar reflexiones

Medio 1: $\sigma_1 = 0$, $\varepsilon_1 = \varepsilon_0$, $\mu_1 = \mu_0$

Medio 2: $\sigma_2 = 0$, $\tilde{\varepsilon}_2 = \varepsilon_0(1-9.95\cdot10^{-9})$, $\mu_2 = \mu_0$

Medio 3: $\sigma_3 = 10^{-2}$, $\varepsilon_3 = 3\varepsilon_0$, $\mu_3 = \mu_0$

$$|\tilde{E}_{in}|_{DI} = \frac{E_{umbral}}{|\tilde{T}_{13}\tilde{T}_{32}\tilde{T}_{21}e^{-(\alpha_2 d_2+\alpha_3 d_3)}|} \qquad |\bar{S}_{in,AV}|_{DI} = \frac{|\tilde{E}_{in}|^2_{DI}}{2\,Re(\tilde{\eta}^*_1)}$$

$$|\tilde{E}_{in}|_{ID} = \frac{E_{umbral}}{|\tilde{T}_{31}\tilde{T}_{12}\tilde{T}_{25}e^{-(\alpha_2 d_2+\alpha_3 d_3)}|} \qquad |\bar{S}_{in,AV}|_{ID} = \frac{|\tilde{E}_{in}|^2_{ID}}{2\,Re(\tilde{\eta}^*_1)}$$

Solución: $\text{Máximo}\{|\bar{S}_{in,AV}|_{DI}, |\bar{S}_{in,AV}|_{ID}\}$

Cada pixel es por $2.5\mu m^2$ luego como cabe esperar es un número muy pequeño.

$\tilde{\gamma}_1 = \sqrt{j\omega\mu_1(\sigma_1+j\omega\varepsilon_1)} = 1.2575\cdot10^{10}j$; $\alpha_1 = 0$; $\qquad \tilde{\eta}_1 = \frac{j\omega\mu_1}{\tilde{\gamma}_1} = 376.73$

$\tilde{\gamma}_2 = \sqrt{j\omega\mu_2(\sigma_2+j\omega\tilde{\varepsilon}_2)} = 625.61 + 1.2575\cdot10^{10}j$; $\alpha_2 = 625.61\,m^{-1}$ $\qquad \tilde{\eta}_2 = \frac{j\omega\mu_2}{\tilde{\gamma}_2} = 376.73 + 1.87423\cdot10^{-5}j$

$\tilde{\gamma}_3 = \sqrt{j\omega\mu_3(\sigma_3+j\omega\varepsilon_3)} = 1.08753 + 2.178\cdot10^{10}j$; $\alpha_3 = 1.08753$ $\qquad \tilde{\eta}_3 = 217.505 + 1.08602\cdot10^{-8}j$

$\tilde{T}_{12} = \frac{2\tilde{\eta}_2}{\tilde{\eta}_1+\tilde{\eta}_2} = 1 + 2.4875\cdot10^{-8}j \qquad \tilde{T}_{13} = 0.732051 + 2.3173\cdot10^{-11}j = \frac{2\tilde{\eta}_3}{\tilde{\eta}_1+\tilde{\eta}_3}$

$\tilde{T}_{21} = \frac{2\tilde{\eta}_1}{\tilde{\eta}_2+\tilde{\eta}_1} = 1 - 2.4875\cdot10^{-8}j \qquad \tilde{T}_{31} = 1.26795 - 2.3173\cdot10^{-11}j = \frac{2\tilde{\eta}_1}{\tilde{\eta}_3+\tilde{\eta}_1}$

$\tilde{T}_{23} = (2\tilde{\eta}_3)/(\tilde{\eta}_2+\tilde{\eta}_3) = 0.732051 - 2.30659\cdot10^{-8}j \qquad \tilde{T}_{32} = 1.26795 + 2.30659\cdot10^{-8}j$

V

$$\tilde{\Gamma}_{21} = \frac{\tilde{\eta}_1 - \tilde{\eta}_2}{\tilde{\eta}_1 + \tilde{\eta}_2} = 1.19187 \cdot 10^{-15} - 2.4875 \cdot 10^{-8} j$$

$$\left.\begin{array}{l} \tilde{\Gamma}_{23} = \dfrac{\tilde{\eta}_3 - \tilde{\eta}_2}{\tilde{\eta}_3 + \tilde{\eta}_2} = -0.267949 - 2.30659 \cdot 10^{-8} j \\ \tilde{\Gamma}_{32} = \dfrac{\tilde{\eta}_2 - \tilde{\eta}_3}{\tilde{\eta}_2 + \tilde{\eta}_3} = 0.267949 + 2.30659 \cdot 10^{-8} j \end{array}\right\} \tilde{\Gamma}_{23} = -\tilde{\Gamma}_{32}$$

$$\tilde{\Gamma}_{31} = \frac{\tilde{\eta}_1 - \tilde{\eta}_3}{\tilde{\eta}_1 + \tilde{\eta}_3} = 0.267949 - 2.3173 \cdot 10^{-11} j$$

Cálculo simple, sin reflexiones

$$\left.\begin{array}{l} |\tilde{E}_{in}|_{DI}^{SIN} = 1.918 \frac{V}{m} \\ |\tilde{E}_{in}|_{ID}^{sin} = 1.918 \frac{V}{m} \end{array}\right\}$$

LAS REFLEXIONES NO SE PUEDEN DESPRECIAR

Calculo con reflexiones

$$|\tilde{E}_{in}|_{DI} = 1.79029 \frac{V}{m}$$

$$|\vec{S}_{in,AV}|_{DI} = 4.25 \frac{mW}{m^2}$$

Expresado en pixels

$$4.25 \frac{mW}{m^2} \left(\frac{1m}{10^6 \mu m}\right)^2 \frac{2.5 \mu m^2}{pixel} = 10^{-11} \frac{mW}{pixel}$$

$$|\tilde{E}_{in}|_{ID} = 1.79029 \frac{V}{m}$$

Identico, por definición de medios, una dirección era suficiente

Los números no se evaluan sólo el enfoque analítico

Problema 3

V

a) Vemos que $\tilde{\varepsilon} = \varepsilon' + \varepsilon'' j$ luego hemos de ver como es la tangente de perdidas en este caso.

Partimos de la ecuación de Ampere-Maxwell

$\nabla \wedge \vec{H}(\vec{r}) = \vec{J}(\vec{r}) + jw\vec{D}(\vec{r})$, suponemos medios LHI

$\nabla \wedge \vec{H}(\vec{r}) = \sigma \vec{E}(\vec{r}) + jw\tilde{\varepsilon}\vec{E}(\vec{r}) = (\sigma + jw(\varepsilon' + \varepsilon'' j))\vec{E}(\vec{r}) \Rightarrow$

$\nabla \wedge \vec{H}(\vec{r}) = (\sigma - w\varepsilon'' + jw\varepsilon')\vec{E}(\vec{r}) \Rightarrow \begin{cases} \vec{J}_c(\vec{r}) = (\sigma - w\varepsilon'')\vec{E}(\vec{r}) \\ \vec{J}_d(\vec{r}) = jw\varepsilon'\vec{E}(\vec{r}) \end{cases}$

$$\tan\theta_E = \frac{|\vec{J}_c(\vec{r})|}{|\vec{J}_d(\vec{r})|} = \frac{\sigma - w\varepsilon''}{w\varepsilon'}$$

Medio 1: $\begin{cases} \sigma_1 = 5\cdot 10^{-3} \\ \mu_1 = 1.1\mu_0 \end{cases}$ $\tilde{\varepsilon}_1 = (\varepsilon_1' + j\varepsilon_1'') \Rightarrow \varepsilon_1' = 2\varepsilon_0$, $\varepsilon_1'' = 0.05\varepsilon_0$

Sustituimos

Medio 1: $\tan\theta_{E1} = \dfrac{\sigma_1 - w\varepsilon_1''}{w\varepsilon_1'} = 0.0199 > 0.01$

Medio 2: $\begin{cases} \sigma_2 = 6.6\cdot 10^{-4} \quad \mu_2 = \mu_0 \\ \varepsilon_2' = 1.05\varepsilon_0 \\ \varepsilon_2'' = 0 \end{cases}$

$\tan\theta_{E2} = \dfrac{\sigma_2 - w\varepsilon_2''}{w\varepsilon_2'} = 0.0112986 > 0.01$

No son ni buenos dieléctricos ni buenos conductores

VII

Medio 1	Medio 2
Fibra de carbono	Aire húmedo
$\tilde{\varepsilon}_1, \mu_1, \sigma_1$	$\tilde{\varepsilon}_2, \mu_2, \sigma_2$

$$\tilde{\gamma} = \sqrt{j\omega\mu(\sigma + j\omega\tilde{\varepsilon})} = \sqrt{\omega\mu((\sigma - \varepsilon''\omega)j - \varepsilon'\omega)}$$

b)

$$\tilde{\gamma}_1 = \sqrt{\omega\mu_1((\sigma_1 - \omega\varepsilon_1'')j - \varepsilon_1'\omega)} = \sqrt{j\omega\mu_1(\sigma_1 + j\omega\tilde{\varepsilon}_1)} = 0.306254 + 31.3913j$$

$$\tilde{\gamma}_2 = \sqrt{\omega\mu_2((\sigma_2 - \omega\varepsilon_2'')j - \varepsilon_2'\omega)} = \sqrt{j\omega\mu_2(\sigma_2 + j\omega\tilde{\varepsilon}_2)} = 0.121352 + 21.686j$$

$$\alpha_1 = Re(\tilde{\gamma}_1) = 0.306252$$

$$\alpha_2 = Re(\tilde{\gamma}_2) = 0.121352$$

$$B_1 = Im(\tilde{\gamma}_1) = 31.3913$$

$$B_2 = Im(\tilde{\gamma}_2) = 21.686$$

$$\tilde{\eta}_1 = \frac{j\omega\mu_1}{\tilde{\gamma}_1} = 279.417 + 2.72599j$$

$$\tilde{\eta}_2 = \frac{j\omega\mu_2}{\tilde{\gamma}_2} = 367.721 + 2.05771j$$

b) $\left|\vec{S}_{AV}\left(\vec{r}_{\substack{Antena\\drone}}\right)\right| = \dfrac{\left|\vec{E}_{Drone}\left(\vec{r}_{Antena}\right)\right|}{2\,Re\left(\tilde{\eta}_{1}^{*}\right)} \Rightarrow \left|\vec{E}_{DRONE}\left(\vec{r}_{\substack{antena\\drone}}\right)\right| = \sqrt{2Re\left(\tilde{\eta}_{1}^{*}\right)\left|\vec{S}_{AV}\left(\vec{r}_{\substack{Antenna\\drone}}\right)\right|}$

$= 1398.54$

c) $\left|\vec{E}_{OPERADOR}\left(\vec{r}_{\substack{Antena\\operador}}\right)\right| = \sqrt{2Re\left(\tilde{\eta}_{2}^{*}\right)\left|\vec{S}_{AV}\left(\vec{r}_{\substack{Antena\\operador}}\right)\right|} = 1917.6$

d) $\tilde{T}_{12} = \dfrac{2\tilde{\eta}_2}{\tilde{\eta}_1+\tilde{\eta}_2} = 1.13644 - 0.00204124j$

e) $\tilde{T}_{21} = \dfrac{2\tilde{\eta}_1}{\tilde{\eta}_1+\tilde{\eta}_2} = 0.863562 + 0.00204124j$

f) $E_{umbral,DRONE} \leq \left|\vec{E}_{OPERADOR}\left(\vec{r}_{\substack{Antena,\\operador}}\right)\right| \cdot e^{\alpha_2(-X_2)}\,|\tilde{T}_{21}|\,e^{\alpha_1(-d_1)}$

$d_1 = 5\cdot10^{-3}\,m$

$X_2^{00} \leq -\dfrac{1}{\alpha_2}\ln\left(\dfrac{E_{umbral,Drone}}{\left|\vec{E}_{OPERADOR}\left(\vec{r}_{\substack{Antena\\operador}}\right)\right|\,|\tilde{T}_{21}|\,e^{-\alpha_1 d_1}}\right) = 182.465\,m$

g) $X_2^{00} \leq -\dfrac{1}{\alpha_2}\left(\dfrac{E_{umbral,OPERADOR}}{\left|\vec{E}_{DRONE}\left(\vec{r}_{\substack{Antena\\drone}}\right)\right|\,|\tilde{T}_{12}|\,e^{-\alpha_1 d_1}}\right) = 186\,m$

h) Si $X_2^{OD} > X_2^{DO} \Rightarrow$ Canal 1 es el limitante

Si $X_2^{OD} < X_2^{DO} \Rightarrow$ Canal 2 es el limitante

Numeros dicen que el Canal 2 es el canal limitante

i) Para saber si se logra o no se comprueba

Mínimo $\{X_2^{DO}, X_2^{OD}\} > 160m$ se logra

otro caso no se logra. Numeros dicen que se logra $182.465m > 160m$

Nota a ayudantes: Se evaluará solo el enfoque analítico

P2

https://mathics.angusgriffith.com/
#cXVlcmllcz1udSUzRDYqMTAlNUUoMTcpJnF1ZXJpZXM9dyUzRDIqUGkqbnUmcXVlcmllcz1OJ
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P3

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