Пример расчета КР. В-1

$$\dot{H}_{xm} = -E_0 \frac{\beta}{\omega\mu} \sin(\gamma_\perp x) e^{-i\beta z};$$

$$\dot{H}_{ym} = 0; \quad \dot{H}_{zm} = iE_0 \frac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cdot e^{-i\beta z}$$

$\tilde{\varepsilon} = \varepsilon_a = \varepsilon_0 \varepsilon_z$

$\mu_a = \mu_0$

1. $$\operatorname{rot} \dot{\bar{H}}_m = i\omega \tilde{\varepsilon} \dot{\bar{E}}_m$$

$$\operatorname{rot} \dot{\bar{H}}_m = \begin{vmatrix} \bar{x}_0 & \bar{y}_0 & \bar{z}_0 \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ \dot{H}_{xm} & \dot{H}_{ym} & \dot{H}_{zm} \end{vmatrix} = \begin{vmatrix} \bar{x}_0 & \bar{y}_0 & \bar{z}_0 \\ \frac{\partial}{\partial x} & 0 & \frac{\partial}{\partial z} \\ \dot{H}_{xm} & 0 & \dot{H}_{zm} \end{vmatrix} =$$

$$= \bar{x}_0\left(0 \cdot \dot{H}_{zm} - 0 \frac{\partial}{\partial z}\right) - \bar{y}_0\left(\frac{\partial \dot{H}_{zm}}{\partial x} - \frac{\partial \dot{H}_{xm}}{\partial z}\right) + \bar{z}_0\left(0 \cdot \frac{\partial}{\partial x} - 0 \cdot \dot{H}_{xm}\right) =$$

$$= \bar{y}_0\left(\frac{\partial \dot{H}_{xm}}{\partial z} - \frac{\partial \dot{H}_{zm}}{\partial x}\right) = \bar{y}_0\left(iE_0 \frac{\beta^2}{\omega\mu} \sin(\gamma_\perp x) \cdot e^{-i\beta z} +\right.$$

$$\left. + iE_0 \frac{\gamma_\perp^2}{\omega\mu} \sin(\gamma_\perp x) e^{-i\beta z}\right) = \bar{y}_0 \, iE_0 \frac{1}{\omega\mu} \cdot \sin(\gamma_\perp x) e^{-i\beta z} \underbrace{(\beta^2 + \gamma_\perp^2)}_{k^2} =$$

$$= i\omega \tilde{\varepsilon} \dot{\bar{E}} \quad \Rightarrow$$

$$\dot{E}_{ym} = \frac{i \frac{k^2}{\omega\mu} E_0 \sin(\gamma_\perp x) \cdot e^{-i\beta z}}{i\omega\tilde{\varepsilon}} = E_0 \sin(\gamma_\perp x) \cdot e^{-i\beta z}$$

$$\Rightarrow \begin{cases} \dot{H}_{xm} = -E_0 \frac{\beta}{\omega\mu} \sin(\gamma_\perp x) \cdot e^{-i\beta z}; \\ \dot{H}_{zm} = iE_0 \frac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cdot e^{-i\beta z}; \\ \dot{E}_{ym} = E_0 \sin(\gamma_\perp x) \cdot e^{-i\beta z}. \end{cases}$$

2. Проверить что при $x = 0$ $\dot{E}_{ym} = 0$ и $\dot{H}_{xm} = 0$

$\dot{E}_{zm} = 0$

$$\dot{E}_{ym} = E_0 \sin(\gamma_\perp \cdot 0) e^{-i\beta z} = 0$$

$$\dot{H}_{xm} = -E_0 \frac{\beta}{\omega\mu} \sin(\gamma_\perp \cdot 0) e^{-i\beta z} = 0$$

3. $$A(t) = Re\left(\dot{A}_m \cdot e^{i\omega t}\right)$$

$$\begin{cases} H_x = -E_0 \dfrac{\beta}{\omega\mu} \sin(\gamma_\perp x) \cdot \cos(\omega t - \beta z) \\ H_z = E_0 \dfrac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cdot \cos(\omega t - \beta z + \frac{\pi}{2}) = \\ \quad = -E_0 \dfrac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cdot \sin(\omega t - \beta z) \\ E_y = E_0 \sin(\gamma_\perp x) \cdot \cos(\omega t - \beta z) \end{cases}$$

$$i = e^{i\frac{\pi}{2}}$$
$$\cos\left(\frac{\pi}{2} + \alpha\right) = -\sin\alpha$$

4. $$\bar{\Pi} = [\bar{E}, \bar{H}] = \begin{vmatrix} \bar{x}_0 & \bar{y}_0 & \bar{z}_0 \\ 0 & E_y & 0 \\ H_x & 0 & H_z \end{vmatrix} = \bar{x}_0 \cdot E_y \cdot H_z - \bar{z}_0 E_y H_x =$$

$$= \bar{x}_0 \left(E_0 \sin(\gamma_\perp x) \cdot \cos(\omega t - \beta z) \cdot i E_0 \frac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cdot \cos(\omega t - \beta z)\right) +$$
$$+ \bar{z}_0 \left(E_0^2 \sin^2(\gamma_\perp x) \cdot \cos^2(\omega t - \beta z) \cdot \frac{\beta}{\omega\mu}\right)$$

$$\tilde{\bar{\Pi}} = \frac{1}{2}[\dot{\bar{E}}_m, \overset{*}{\bar{H}}_m] = \frac{1}{2} \begin{vmatrix} \bar{x}_0 & \bar{y}_0 & \bar{z}_0 \\ 0 & \dot{E}_{ym} & 0 \\ \overset{*}{H}_{xm} & 0 & \overset{*}{H}_{zm} \end{vmatrix} = \frac{1}{2} \bar{x}_0 \dot{E}_{ym} \overset{*}{H}_{zm} - \frac{1}{2} \bar{z}_0 \dot{E}_{ym} \overset{*}{H}_{xm}$$

$$= \frac{1}{2} \bar{x}_0 \left(E_0 \sin(\gamma_\perp x) \cdot \cancel{e^{-i\beta z}} \cdot \left(-i \cdot E_0 \frac{\gamma_\perp}{\omega\mu} \cos(\gamma_\perp x) \cancel{e^{i\beta z}}\right)\right) +$$
$$+ \frac{1}{2} \bar{z}_0 E_0 \sin(\gamma_\perp x) \cdot \cancel{e^{-i\beta z}} \cdot E_0 \frac{\beta}{\omega\mu} \sin(\gamma_\perp x) \cancel{e^{i\beta z}}$$

$$\bar{\Pi}_{cp} = Re\, \tilde{\bar{\Pi}} = \frac{1}{2} \bar{z}_0 E_0^2 \sin^2(\gamma_\perp x) \cdot \frac{\beta}{\omega\mu}$$

5. $$\dot{\bar{j}}_m = [\underset{\bar{x}_0}{\underset{\shortparallel}{\bar{n}_0}}, \dot{\bar{H}}_m] = \begin{vmatrix} \bar{x}_0 & \bar{y}_0 & \bar{z}_0 \\ 1 & 0 & 0 \\ \dot{H}_{xm} & 0 & \dot{H}_{zm} \end{vmatrix} = -\bar{y}_0 \cdot \dot{H}_{zm} =$$

$$= -\bar{y}_0\, i E_0 \frac{\gamma_\perp}{\omega\mu} \cdot \cos(\gamma_\perp x) \cdot e^{-i\beta z}$$

6. $$\beta = k\cdot\sqrt{1-\left(\frac{\gamma_\perp}{k}\right)^2} \qquad k^2=\beta^2+\gamma_\perp^2$$

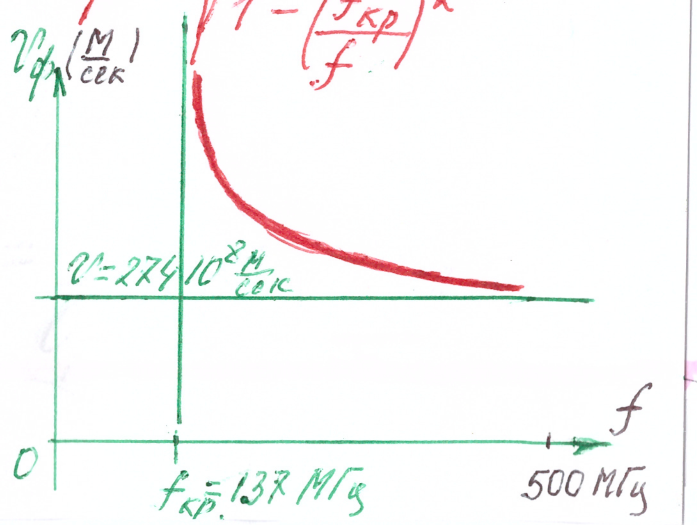
при $\frac{\gamma_\perp}{k}=0,6 \Rightarrow \beta = 0,8k = 0,8\cdot\omega\sqrt{\varepsilon_r\varepsilon_0\mu_0}$;

7. **КР**

$$f_{кр.} = \frac{\gamma_\perp}{2\pi\sqrt{\varepsilon_a\mu_a}} = \frac{\gamma_\perp\cdot\lambda\cdot c}{2\pi\sqrt{\varepsilon}\cdot\lambda} = \frac{0,6\cdot 3\cdot 10^8}{\sqrt{1,2}\cdot 1,2} = 137\ МГц$$

$0,6 = \frac{\gamma_\perp\cdot\lambda}{2\pi}$

$$v_ф = \frac{v}{\sqrt{1-\left(\frac{f_{кр}}{f}\right)^2}}, \qquad v = \frac{3\cdot 10^8}{\sqrt{\varepsilon}} = 2,74\cdot 10^8$$



8. $$\lambda_x = \frac{2\pi}{\gamma_\perp};\quad \text{при } \frac{\gamma_\perp}{k}=0,6 \Rightarrow \lambda_x = \frac{2\pi\cdot\lambda}{0,6\cdot 2\pi\sqrt{\varepsilon_r}} = 1,826\ м, \quad \varepsilon_r = 1,2$$

где $\lambda = \frac{c}{f} = \frac{3\cdot 10^8}{250\cdot 10^6} = 1,2\ м$

$0 \le x \le 2\lambda_x$

$z = \frac{\lambda}{8}$; $t = \frac{T}{4}$ $\left(T = \frac{1}{f}\right)$

9. $$P_{п.} = \frac{1}{2} R_s \left|\dot{H}_m^s\right|^2 \Delta S, \qquad \Delta S = 1\ м^2$$

$$\dot{H}_{zm} = E_0\frac{\gamma_\perp}{\omega\mu} = E_0\frac{0,6k}{\omega\mu} = E_0\frac{0,6\cdot\omega\sqrt{\varepsilon_r\varepsilon_0\mu}}{\omega\mu} = E_0\frac{0,6\cdot\sqrt{\varepsilon_r}}{120\pi}\ \left(\frac{А}{м}\right)$$

при $E_0 = 30\ \frac{В}{м}$, $\varepsilon_r = 1,2$

$$R_S = \sqrt{\frac{\pi f\mu_0}{\sigma}} = \sqrt{\frac{\pi\cdot 250\cdot 10^6\cdot 4\pi\cdot 10^{-7}}{34\cdot 10^6}} = 0,005385\ Ом$$

$$P_{п.} = 7,365\cdot 10^{-6}\ Вт$$

$\dot{H}_{zm} = 0;\quad \dot{E}_{zm} = E_0 \sin(\gamma_\perp x) \cdot e^{-i\beta z};$ В-2

1. $$\gamma_\perp^2 \dot{E}_{mx} = -i\left(\beta \frac{\partial \dot{E}_{mz}}{\partial x} + \omega\mu \underbrace{\frac{\partial \dot{H}_{mz}}{\partial y}}_{=0}\right);$$

$$\gamma_\perp^2 \dot{E}_{my} = -i\left(\beta \underbrace{\frac{\partial \dot{E}_{mz}}{\partial y}}_{=0} - \omega\mu \underbrace{\frac{\partial \dot{H}_{mz}}{\partial x}}_{=0}\right);$$

$$\gamma_\perp^2 \dot{H}_{mx} = i\left(\omega\varepsilon \underbrace{\frac{\partial \dot{E}_{mz}}{\partial y}}_{=0} - \beta \underbrace{\frac{\partial \dot{H}_{mz}}{\partial x}}_{=0}\right);$$

$$\gamma_\perp^2 \dot{H}_{my} = -i\left(\omega\varepsilon \frac{\partial \dot{E}_{mz}}{\partial x} + \beta \underbrace{\frac{\partial \dot{H}_{mz}}{\partial y}}_{=0}\right);$$

$$\gamma_\perp^2 \dot{E}_{mx} = -i\beta \frac{\partial \dot{E}_{mz}}{\partial x} = -i\beta E_0 \gamma_\perp \cos(\gamma_\perp x) e^{-i\beta z};$$

$$\gamma_\perp^2 \dot{H}_{my} = -i\omega\varepsilon \frac{\partial \dot{E}_{mz}}{\partial x} = -i\omega\varepsilon E_0 \gamma_\perp \cos(\gamma_\perp x) \cdot e^{-i\beta z};$$

$$\begin{cases} \dot{E}_{mz} = E_0 \sin(\gamma_\perp x) e^{-i\beta z}; \\ \dot{E}_{mx} = \dfrac{-i\beta}{\gamma_\perp} E_0 \cdot \cos(\gamma_\perp x) e^{-i\beta z}; \\ \dot{H}_{my} = \dfrac{-i\omega\varepsilon E_0}{\gamma_\perp} \cos(\gamma_\perp x) e^{-i\beta z}. \end{cases}$$ 3