# PENETRATION DEPTH IN FERRITE AND RECOMMENDATION FOR THE THICKNESS

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- **General formula => It is the skin depth for the case of a good conductor (metal) at not extremely high frequencies**

- **Example on the case of the (fitted) 4A4 ferrite => Just to have an idea for an approximate (simplified) case… Should be re-done for the ferrite under consideration with the measured electro-magnetic properties…**

- **Practical recommendation for the ferrite's thickness**

# GENERAL FORMULA

$$\delta(f) = \frac{c}{2\pi f} \times \frac{1}{\mathrm{Re}\left[\sqrt{1 - \varepsilon_{rc}(f)\,\mu_{rc}(f)}\right]}$$

**with**    $f$    **frequency**

         $c$    **speed of light**

$$\varepsilon_{rc}(f) = \varepsilon' - j\,\varepsilon'' = \varepsilon'\left(1 - j\tan\delta_\varepsilon\right)$$    **relative complex permittivity**
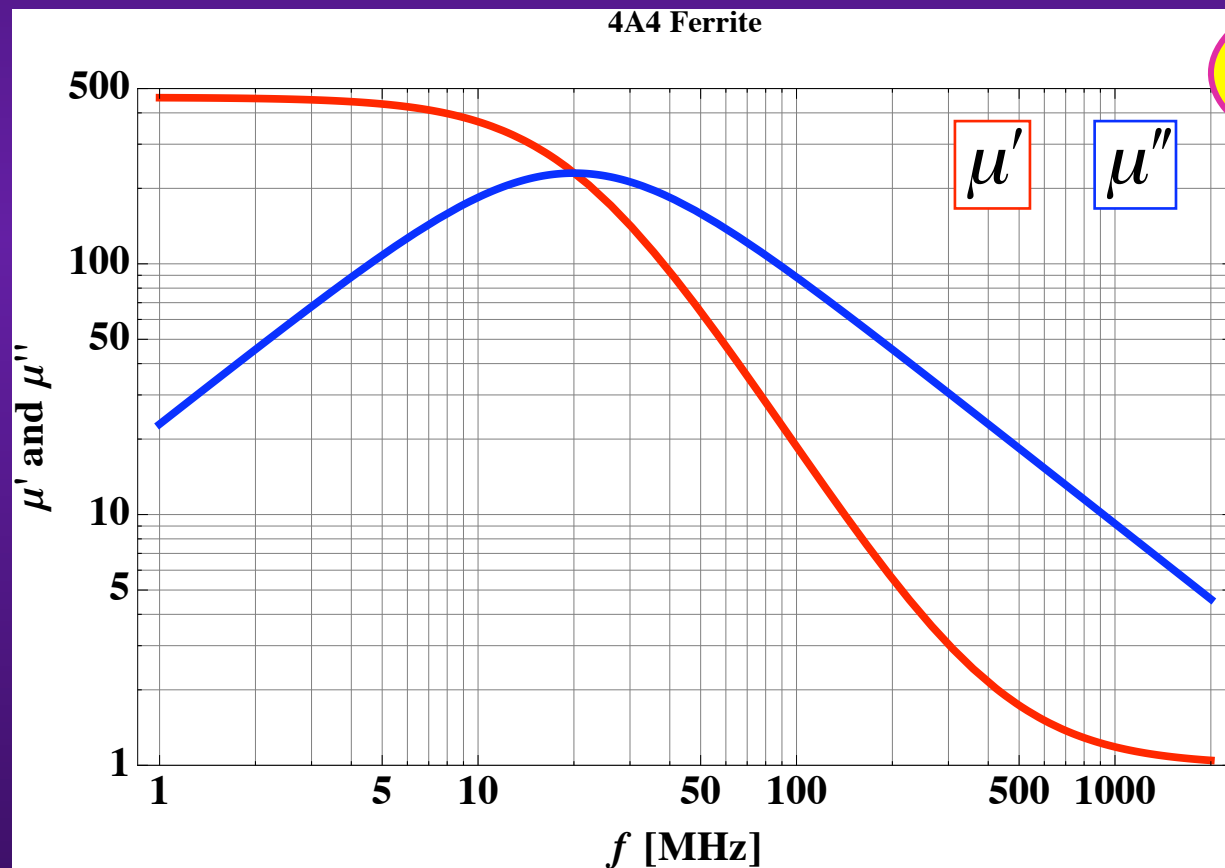
$$\mu_{rc}(f) = \mu' - j\,\mu'' = \mu'\left(1 - j\tan\delta_\mu\right)$$    **relative complex permeability**

$$\mu_{rc}(f) \approx 1 + \frac{460}{1 + j\,\dfrac{f}{2 \times 10^7}}$$

$$\varepsilon_{rc}(f) \approx \varepsilon'$$

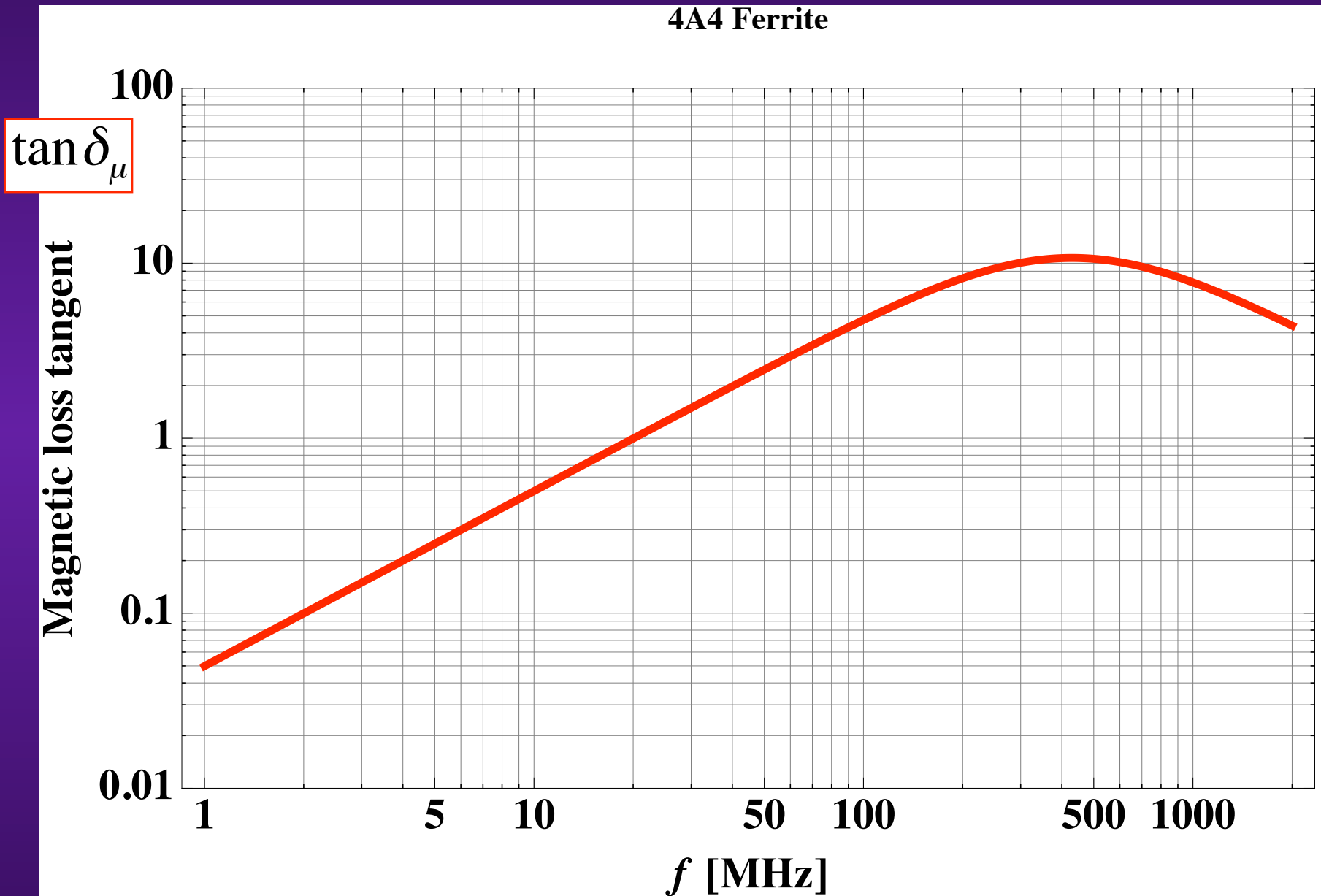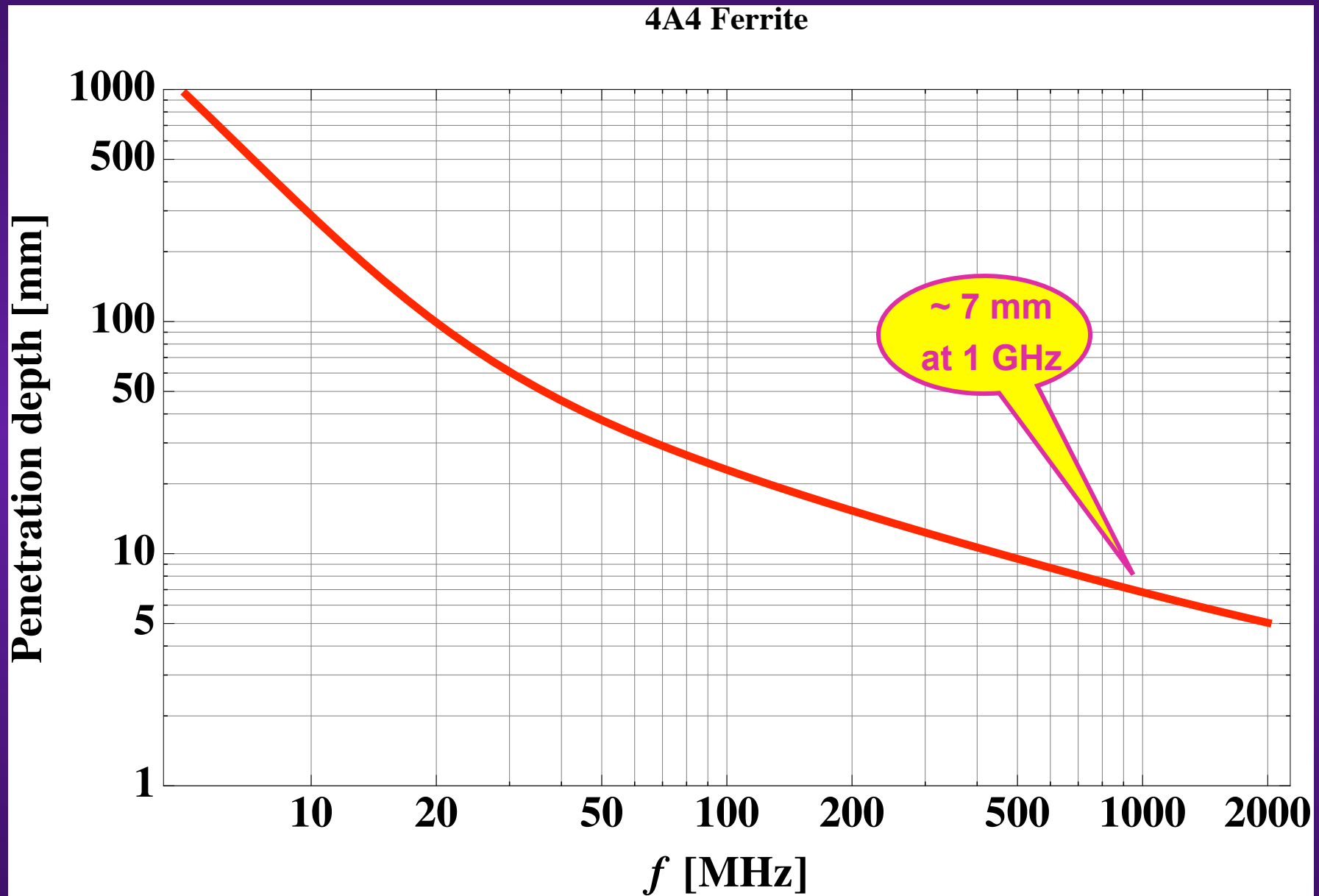**The ε" is usually small and can be neglected**

$$\varepsilon' \approx 12$$

$$\sigma \approx 10^{-6}\ S/m$$

$$\varepsilon_0$$ **vacuum permittivity**

**4A4 Ferrite**

$\mu'$   $\mu''$

$\mu'$ and $\mu''$

$f$ [MHz]

**4A4 Ferrite**



$\tan \delta_\mu$

Magnetic loss tangent

$f$ [MHz]

4A4 Ferrite

# PRACTICAL RECOMMENDATION FOR THE FERRITE'S THICKNESS

◆ **To damp a mode at a frequency *f*, a ferrite's thickness equal to the penetration depth at frequency *f* is an upper limit => It is enough to have less, say (as a 1st guideline, but it should be confirmed by simulation for the particular case under study):**

**Ferrite thickness ≈ penetration depth / 2**

◆ **Example with the previous (fitted) 4A4 ferrite: if one wants to damp a mode at 1 GHz, a thickness of ~ 3-4 mm is OK**

◆ **Remarks:**

  ▪ **Depending on the frequency, one has to optimize the ferrite to be used**

  ▪ **A lower limit for the ferrite's thickness is given by mechanical considerations => Should be > few mm for ferrite's tiles. For plasma sprayed ferrite, the thickness is dictated by the technology (maximum of few hundreds microns)**