Electronic Supplementary Information

Derivations of curves in Fig. 6

■ Curve A:

Although the two shell model[26] can be used to calculate Re(f_{CM}) of cells in this study, the single shell model[26,27] simplifies the calculation and brings a similar result. In this model, f_{CM} is expressed as:

$$f_{CM} = \frac{\varepsilon^*_{cell} - \varepsilon^*_m}{\varepsilon^*_{cell} + 2\varepsilon^*_m}, \qquad \text{(supplementary-a)}$$

$$\varepsilon^*_{cell} = \frac{\left(\frac{d_c}{d_{cp}}\right)^3 + 2\left(\frac{\varepsilon^*_{cp} - \varepsilon^*_m}{\varepsilon^*_{cp} + 2\varepsilon^*_m}\right)}{\left(\frac{d_c}{d_{cp}}\right)^3 - \left(\frac{\varepsilon^*_{cp} - \varepsilon^*_m}{\varepsilon^*_{cp} + 2\varepsilon^*_m}\right)}, \qquad \text{(supplementary-b)}$$

where d_c and d_{cp} are the diameters of the cell and the cytoplasm, ε^*_m and ε^*_{cp} are the complex permittivities of cell membrane and cytoplasm.

$$\varepsilon^*_{p,m} = \varepsilon_0 \varepsilon_{p,m} - j\frac{\sigma_{p,m}}{2\pi f} \qquad (6)$$

■ Curve B:

V_L/V of cell medium is calculated from:

$$V_L / V = \mathrm{Re}\left(\frac{j2\pi f C_D R_L}{1 + j2\pi f (C_D + C_L) R_L}\right). \qquad (4)$$

where $C_D = \varepsilon_0\varepsilon_D A/t$, $C_L = \varepsilon_0\varepsilon_L A/d$, $R_L = \sigma_L d/A$; ε_D and t are the dielectric constant and the thickness of SU-8, ε_L, σ_L, and d are the dielectric constant, conductivity, and thickness of cell medium.

■ Curve C:

V_L/V of water can be calculated as curve B by substituting ε_L and σ_L of water.

■ Curve D:

Re(f_{CM}) of beads is calculated from eqn (6) and (7).

$$f_{CM} = \frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*} \tag{7}$$

$$\varepsilon_{p,m}^* = \varepsilon_0 \varepsilon_{p,m} - j\frac{\sigma_{p,m}}{2\pi f} \tag{6}$$

■ Curve E:

Modified Re(f_{CM}) is obtained by dividing curve D by 400 to shift the cross-over frequency from 2 MHz to 5 kHz.

■ Weighted Re(f_{CM}) of cells is the product of curve A and B.

■ Weighted Re(f_{CM}) of beads is the product of curve C and E.

The related parameters are listed below:

	Material	Relative permittivity	Conductivity (S/m)	Dimension (μm)
Polystyrene bead solution	Medium	80	1×10^{-4}	Thickness: 200
	Bead	2.5	1.45×10^{-2}	Diameter: 5
Neuro-2a solution	Medium	78	4.8×10^{-2}	Thickness: 200
	Membrane	10	1×10^{-8}	Thickness: 5×10^{-3}
	Cytoplasm	60	5×10^{-1}	Diameter: 5
Dielectric	SU8	3	—	Thickness: 5

Video 1: The video for Fig. 4, which is played at an 8x speed.

Video 2: The video for Fig. 5, which is played at a 2x speed.