

## References (database v5.0, 21.08.2025)

**References for the low frequency dielectric conductivities** listed in our material properties database. Values for tissues of which the properties are not available in the literature are substituted with values from other tissues. In these cases, the tissue used for the value is listed instead of a reference. The rational for each individual substitution is provided in the Rational for Tissue Substitutions.

Tissue	Low Frequency Conductivity
Air	<a href="#">Gabriel et al., 1996</a>
Bile	<a href="#">Gabriel et al., 2009</a> <a href="#">Geddes and Baker, 1967</a>
Blood	<a href="#">Gabriel et al., 2009</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Hahn et al., 1980</a> <a href="#">Mohapatra and Hill, 1975</a> <a href="#">Istuk et al., 2021</a>
Blood Plasma	<a href="#">Geddes and Baker, 1967</a>
Blood Serum	<a href="#">Geddes and Baker, 1967</a>
Blood Vessel Wall	<a href="#">Gabriel et al., 1996</a>
Bone	<a href="#">Geddes and Baker, 1967</a>
Bone (Cancellous)	<a href="#">Saha and Williams, 1989</a> <a href="#">Sierpowska et al., 2003</a> <a href="#">Gabriel et al., 1996</a>
Bone (Cortical)	<a href="#">Balmer et al., 2018</a>
Bone (Cortical) - Accross	<a href="#">Reddy and Saha, 1984</a>
Bone (Cortical) - Along	<a href="#">Reddy and Saha, 1984</a>
Bone (Cortical) - Around	<a href="#">Reddy and Saha, 1984</a>
Bone Marrow (Red)	<a href="#">Ibrahim et al., 2019</a> <a href="#">Padhani et al., 2013</a> <a href="#">Sigman et al., 1936</a>
Bone Marrow (Yellow)	<a href="#">Gabriel et al., 1996</a> <a href="#">Haacke et al., 1991</a> <a href="#">Padhani et al., 2013</a>

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Tissue	Low Frequency Conductivity
Brain	<a href="#">Akhtari et al., 2006</a> <a href="#">Baysal et al., 2004</a> <a href="#">Cohen et al., 1983</a> <a href="#">Dabek et al., 2016</a> <a href="#">Dannhauer et al., 2011</a> <a href="#">Eriksen et al., 1990</a> <a href="#">Freygang and Landau, 1955</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Goncalves et al., 2003a</a> <a href="#">Goncalves et al., 2003b</a> <a href="#">Gutierrez et al., 2004</a> <a href="#">Haacke et al., 1991</a> <a href="#">Hampe et al., 2018</a> <a href="#">Kim et al., 2014</a> <a href="#">Lee et al., 2015</a> <a href="#">Oostendorp et al., 2000</a> <a href="#">Van Harrevelde et al., 1963</a>
Brain (Grey Matter)	<a href="#">Chauhan et al., 2018</a> <a href="#">Gattellaro et al., 2009</a> <a href="#">Gurler et al., 2016</a> <a href="#">Huang et al., 2017</a> <a href="#">Koessler et al., 2015</a> <a href="#">Latikka et al., 2001</a> <a href="#">Michel et al., 2017</a> <a href="#">Oypornkochagorn et al., 2014</a> <a href="#">Pierpaoli et al., 1996</a> <a href="#">Raicu et al., 1998</a> <a href="#">Rullmann et al., 2009</a> <a href="#">Sekino et al., 2005</a> <a href="#">Sorensen et al., 1999</a> <a href="#">Stoy et al., 1982</a> <a href="#">Ulug et al., 1999</a> <a href="#">Van Harrevelde et al., 1963</a> <a href="#">vanLier et al., 2012</a> <a href="#">Voigt et al., 2011</a> <a href="#">Wang et al., 2010</a> <a href="#">Yedlin et al., 1974</a> <a href="#">Zhang et al., 2013</a> <a href="#">Gabriel et al., 1996</a>
Brain (Grey Matter) - x along	<a href="#">Yedlin et al., 1974</a>
Brain (Grey Matter) - y across	<a href="#">Yedlin et al., 1974</a>
Brain (Grey Matter) - z Normal to Surface Axis	<a href="#">Yedlin et al., 1974</a>

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Tissue	Low Frequency Conductivity
Brain (White Matter)	<a href="#">Gattellaro et al., 2009</a> <a href="#">Gurler et al., 2016</a> <a href="#">Horger et al., 2009</a> <a href="#">Huang et al., 2017</a> <a href="#">Huhndorf et al., 2013</a> <a href="#">Koessler et al., 2015</a> <a href="#">Latikka et al., 2001</a> <a href="#">Oypornkochagorn et al., 2014</a> <a href="#">Pierpaoli et al., 1996</a> <a href="#">Ropella et al., 2017</a> <a href="#">Rullmann et al., 2009</a> <a href="#">Sekino et al., 2005</a> <a href="#">Sorensen et al., 1999</a> <a href="#">Stoy et al., 1982</a> <a href="#">Ulug et al., 1999</a> <a href="#">Voigt et al., 2009</a> <a href="#">Voigt et al., 2011</a> <a href="#">Zhang et al., 2013</a> <a href="#">Gabriel et al., 1996</a>
Brain (White Matter) - across fibers	<a href="#">Güllmar et al., 2010</a> <a href="#">Jahng et al., 2021</a> <a href="#">Nicholson, 1965</a>
Brain (White Matter) - along fibers	<a href="#">Chauhan et al., 2018</a> <a href="#">Jahng et al., 2021</a> <a href="#">Nicholson, 1965</a>
Breast Fat	Fat
Breast Gland	<a href="#">Jossinet, 1998</a>
Bronchi	<a href="#">Sanchez et al., 2013</a>
Bronchi lumen	Air
Cartilage	<a href="#">Aoki et al., 2012</a> <a href="#">Binette et al., 2004</a> <a href="#">Juras et al., 2007</a> <a href="#">Morita et al., 2012</a> <a href="#">de Visser et al., 2008</a>
Cerebellum	<a href="#">Hiwatashi et al., 2014</a> <a href="#">Huhndorf et al., 2013</a> <a href="#">Voigt et al., 2009</a> <a href="#">Nicholson and Freeman, 1975</a>
Cerebellum - x	<a href="#">Nicholson and Freeman, 1975</a>
Cerebellum - y	<a href="#">Nicholson and Freeman, 1975</a>
Cerebellum - z	<a href="#">Nicholson and Freeman, 1975</a>

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<b>Tissue</b>	<b>Low Frequency Conductivity</b>
Cerebrospinal Fluid	<a href="#">Baumann et al., 1997</a> <a href="#">Chauhan et al., 2018</a> <a href="#">Cohen et al., 1983</a> <a href="#">Gurler et al., 2016</a> <a href="#">Haacke et al., 1991</a> <a href="#">Huang et al., 2017</a> <a href="#">Jahng et al., 2021</a> <a href="#">Lee et al., 2016</a> <a href="#">Michel et al., 2017</a> <a href="#">Oypornkochagorn et al., 2014</a> <a href="#">Pierpaoli et al., 1996</a> <a href="#">Ropella et al., 2017</a> <a href="#">Sorensen et al., 1999</a> <a href="#">Ulug et al., 1999</a> <a href="#">vanLier et al., 2011</a> <a href="#">Voigt et al., 2009</a> <a href="#">Voigt et al., 2011</a> <a href="#">Zhang et al., 2013</a> <a href="#">Gabriel et al., 2009</a>
Cervix	<a href="#">Gabriel et al., 2009</a> <a href="#">Gabriel et al., 1996</a>
Commissura Anterior	Brain (White Matter)
Commissura Posterior	Brain (White Matter)
Connective Tissue	<a href="#">Jossinet, 1998</a>
Diaphragm	Muscle
Diaphragm - Parallel	Muscle - Parallel
Diaphragm - Perpendicular	Muscle - Perpendicular
Dorsal Column	<a href="#">Rank and BeMent, 1965</a>
Dorsal Column - Across	<a href="#">Rank and BeMent, 1965</a>
Dorsal Column - Along	<a href="#">Rank and BeMent, 1965</a>
Ductus Deferens	Blood Vessel Wall
Dura	<a href="#">Oozeer et al., 2005</a> <a href="#">Sin and Coburn, 1983</a>
Epididymis	Ovary
Esophagus	Large Intestine
Esophagus Lumen	Air
Extracellular Fluids	<a href="#">Baysal et al., 2004</a> <a href="#">Karatag et al., 2015</a> <a href="#">Razek and Samir, 2019</a>
Eye (Aqueous Humor)	Cerebrospinal Fluid
Eye (Choroid)	Blood
Eye (Ciliary Body)	Muscle
Eye (Cornea)	Eye (Sclera)
Eye (Iris)	Muscle
Eye (Lens)	<a href="#">Pauly and Schwan, 1964</a>
Eye (Retina)	Brain (Grey Matter)
Eye (Sclera)	<a href="#">Gabriel et al., 1996</a>
Eye (Vitreous Humor)	<a href="#">Pauly and Schwan, 1964</a> <a href="#">Meral and Bilgili, 2010</a>
Eye Lens (Cortex)	<a href="#">Pauly and Schwan, 1964</a>
Eye Lens (Nucleus)	<a href="#">Pauly and Schwan, 1964</a>

Tissue	Low Frequency Conductivity
Fat	<a href="#">Gabriel et al.,2009</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Hahn et al., 1980</a> <a href="#">Hershkovic et al., 2019</a> <a href="#">Jossinet, 1998</a> <a href="#">Lee et al., 2016</a> <a href="#">Rush et al., 1963</a> <a href="#">Schwan and Kay, 1957</a> <a href="#">Gabriel et al., 1996</a>
Fat (Average Infiltrated)	Fat
Fat (Not Infiltrated)	Fat
Gallbladder	Bladder Wall
Heart Lumen	Blood
Heart Muscle	<a href="#">Cinca et al., 1997</a> <a href="#">Ellenby et al., 1987</a> <a href="#">Fallert et al., 1993</a> <a href="#">Gabriel et al.,2009</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Hahn et al., 1980</a> <a href="#">Schwan and Kay, 1957</a> <a href="#">Smith et al., 1995</a> <a href="#">Tsai et al., 2002</a> <a href="#">Gabriel et al., 1996</a>
Heart Muscle - Longitudial	<a href="#">Rush et al., 1963</a> <a href="#">Steendijk et al., 1994</a>
Heart Muscle - Longitudial	<a href="#">Rush et al., 1963</a> <a href="#">Steendijk et al., 1994</a>
Hippocampus	Brain (Grey Matter)
Hypophysis	<a href="#">Hiwatashi et al., 2014</a>
Hypothalamus	Brain (Grey Matter)
Intervertebral Disc	Cartilage
Kidney	<a href="#">Hahn et al., 1980</a> <a href="#">Stoy et al., 1982</a> <a href="#">Gabriel et al., 1996</a>
Kidney (Cortex)	Kidney
Kidney (Medulla)	Kidney
Large Intestine	<a href="#">Gabriel et al., 1996</a>
Large Intestine Lumen	Muscle
Larynx	Cartilage
Liver	<a href="#">Gabriel et al.,2009</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Haemmerich et al., 2009</a> <a href="#">Hahn et al., 1980</a> <a href="#">Raicu et al., 1998</a> <a href="#">Rush et al., 1963</a> <a href="#">Schwan and Kay, 1957</a> <a href="#">Stoy et al., 1982</a> <a href="#">Zurbuchen et al., 2010</a>

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<b>Tissue</b>	<b>Low Frequency Conductivity</b>
Lung	<a href="#">Geddes and Baker, 1967</a> <a href="#">Schwan and Kay, 1957</a>
Lung (Deflated)	<a href="#">Gabriel et al., 2009</a> <a href="#">Hahn et al., 1980</a> <a href="#">Rush et al., 1963</a>
Lung (Inflated)	<a href="#">Gabriel et al., 2009</a> <a href="#">Hahn et al., 1980</a> <a href="#">Rush et al., 1963</a>
Lymphnode	Spleen
Mandible	Bone (Cortical) <a href="#">Epstein and Foster, 1983</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Rush et al., 1963</a>
Medulla Oblingata	<a href="#">Michel et al., 2017</a>
Meniscus	Cartilage
Mucous Membrane	Muscle
Midbrain	<a href="#">Michel et al., 2017</a>
Muscle	<a href="#">Gabriel et al., 2009</a> <a href="#">Geddes et al., 1967</a> <a href="#">Haacke et al., 1991</a> <a href="#">Stoy et al., 1982</a> <a href="#">Gabriel et al., 1996</a>
Muscle - Parallel	<a href="#">Gabriel et al., 2009</a> <a href="#">Epstein and Foster, 1983</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Rush et al., 1963</a>
Muscle - Perpendicular	<a href="#">Gabriel et al., 2009</a> <a href="#">Epstein and Foster, 1983</a> <a href="#">Geddes and Baker, 1967</a> <a href="#">Rush et al., 1963</a>
Nerve	Brain (White Matter)
Ovary	<a href="#">Gabriel et al., 1996</a>
Pancreas	<a href="#">Geddes and Baker, 1967</a>
Patella	Bone (Cortical)
Penis	Blood Vessel Wall
Pharynx	Air
Pineal Body	Thyroid Gland
Placenta	Blood
Pons	<a href="#">Hiwatashi et al., 2014</a> <a href="#">Michel et al., 2017</a>
Prostate	<a href="#">Halter et al., 2007</a>
Salivary Gland	Prostate
SAT (Subcutaneous Fat)	Fat
Scalp	<a href="#">Armugam et al., 2017</a> <a href="#">Baysal et al., 2004</a> <a href="#">Cohen et al., 1983</a> <a href="#">Dabek et al., 2016</a> <a href="#">Dannhauer et al., 2011</a> <a href="#">Eriksen et al., 1990</a> <a href="#">Fernandez-Corazza et al., 2018</a> <a href="#">Gutierrez et al., 2004</a> <a href="#">Huang et al., 2017</a>

Tissue	Low Frequency Conductivity
Seminal vesicle	Prostate
Skin	<a href="#">Hershkovic et al., 2019</a> <a href="#">Yamamoto and Yamamoto, 1976</a> <a href="#">Wake et al., 2016</a>
Skull	<a href="#">Akhtari et al., 2002</a> <a href="#">Armugam et al., 2017</a> <a href="#">Baysal et al., 2004</a> <a href="#">Clerc et al., 2005</a> <a href="#">Cohen et al., 1983</a> <a href="#">Dabek et al., 2016</a> <a href="#">Dannhauer et al., 2011</a> <a href="#">Eriksen et al., 1990</a> <a href="#">Fernandez-Corazza et al., 2018</a> <a href="#">Goncalves et al., 2003a</a> <a href="#">Goncalves et al., 2003b</a> <a href="#">Gutierrez et al., 2004</a> <a href="#">Huang et al., 2017</a> <a href="#">Law et al., 1993</a> <a href="#">Oostendorp et al., 2000</a>
Skull (Compact)	<a href="#">Fernandez-Corazza et al., 2018</a>
Skull (Cancellous)	<a href="#">Gabriel et al., 2009</a>
Skull (Cortical)	<a href="#">Gabriel et al., 2009</a>
Skull (Inner Compact)	<a href="#">Akhtari et al., 2002</a>
Skull (Outer Compact)	<a href="#">Akhtari et al., 2002</a> <a href="#">Tang et al., 2008</a>
Skull (Spongy)	<a href="#">Akhtari et al., 2002</a> <a href="#">Fernandez-Corazza et al., 2018</a>
Skull (Suture)	<a href="#">Law et al., 1993</a> <a href="#">Tang et al., 2008</a>
Small Intestine	Large Intestine
Small Intestine Lumen	Muscle
Spinal Cord	<a href="#">Facon et al., 2005</a> <a href="#">Hasseltine et al., 2005</a> <a href="#">Song et al., 2011</a>
Spleen	<a href="#">Geddes and Baker, 1967</a> <a href="#">Hahn et al., 1980</a> <a href="#">Stoy et al., 1982</a> <a href="#">Gabriel et al., 1996</a>
Stomach	Large Intestine
Stomach Lumen	Muscle
Tendon\Ligament	<a href="#">Gabriel et al., 1996</a>
Testis	Ovary
Thalamus	<a href="#">Michel et al., 2017</a>
Thymus	Spleen and Fat
Thyroid Gland	<a href="#">Gabriel et al., 1996</a>
Tongue	Muscle

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Tooth	Bone (Cortical)
Tooth (Dentine)	Bone (Cortical)
Tooth (Enamel)	Bone (Cortical)
Trachea Lumen	Air
Ureter\Urethra	Blood Vessel Wall
Urinary Bladder Wall	<a href="#">Keshtkar et al., 2006</a>
Urine	<a href="#">Geddes and Baker, 1967</a>
Uterus	<a href="#">Gabriel et al., 1996</a>
Vagina	Large Intestine
Vertebrae	Bone (Cortical)
Water	<a href="#">Aldosky and Shamdeen, 2011</a>

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