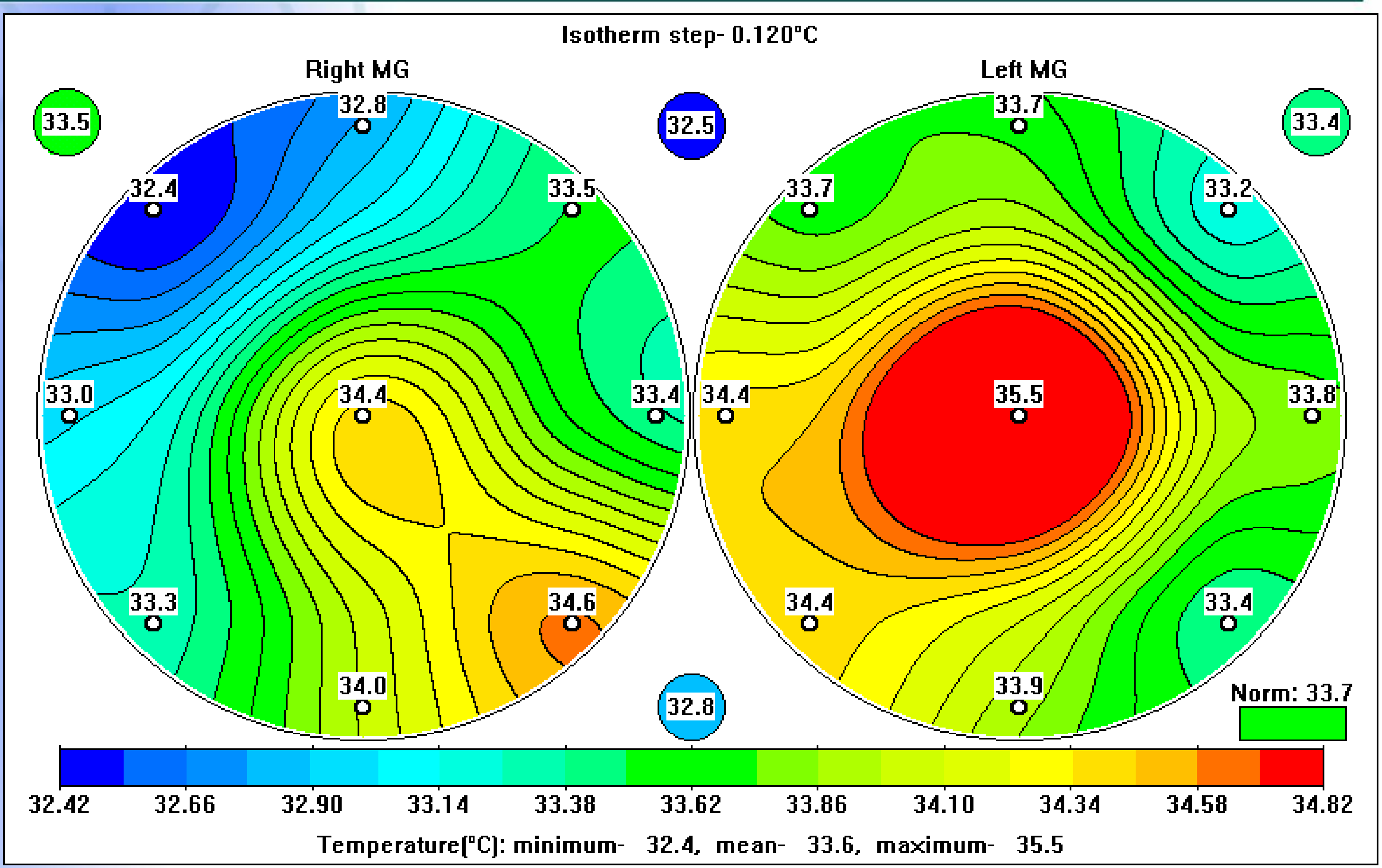
Deep Temperature Measurement

RTM – 01 – RES Imaging System

Items	Specifications
Accuracy of measuring the averaged internal temperature, when a temperature is 32 - 38 °C, °C	**± 0,2**
Time required for measuring internal temperature at a point, seconds	**6**
Antenna diameter, mm	**39**
Accuracy of measuring the skin temperature, °C	**± 0,2**
Time required for measuring skin temperature at a point, when the temperature is 32 - 38 °C, seconds	**1**
Device mass, kg	**4**
Power consumption, Watt	**5**

Temperature Field



Results of the measurements can be displayed in different modes

Three Types of Antennas

F=3.8 D=44mm
H=67mm

F=1.15 D=38mm
H=45mm

F=1.15 D=38mm
H=7mm

Main Principles

$$P = kT_{rad}\Delta f \qquad T_{rad} = \int_{-\infty}^{\infty} T(r) * P(r)\,dV$$

$$k = 1.38 * 10^{-23}\ \frac{J}{K} \qquad \Delta f - \text{Frequency\_Band}$$

T(r)-Thermodynamic Temperature,
r-Current Coordinate
P(r)- The Radiometric Weighting Function

$$P(r) = \frac{\sigma \left|\overline{E}(r)\right|^2}{\int_{-\infty}^{\infty} \sigma \left|\overline{E}(r)\right|^2 dV}$$

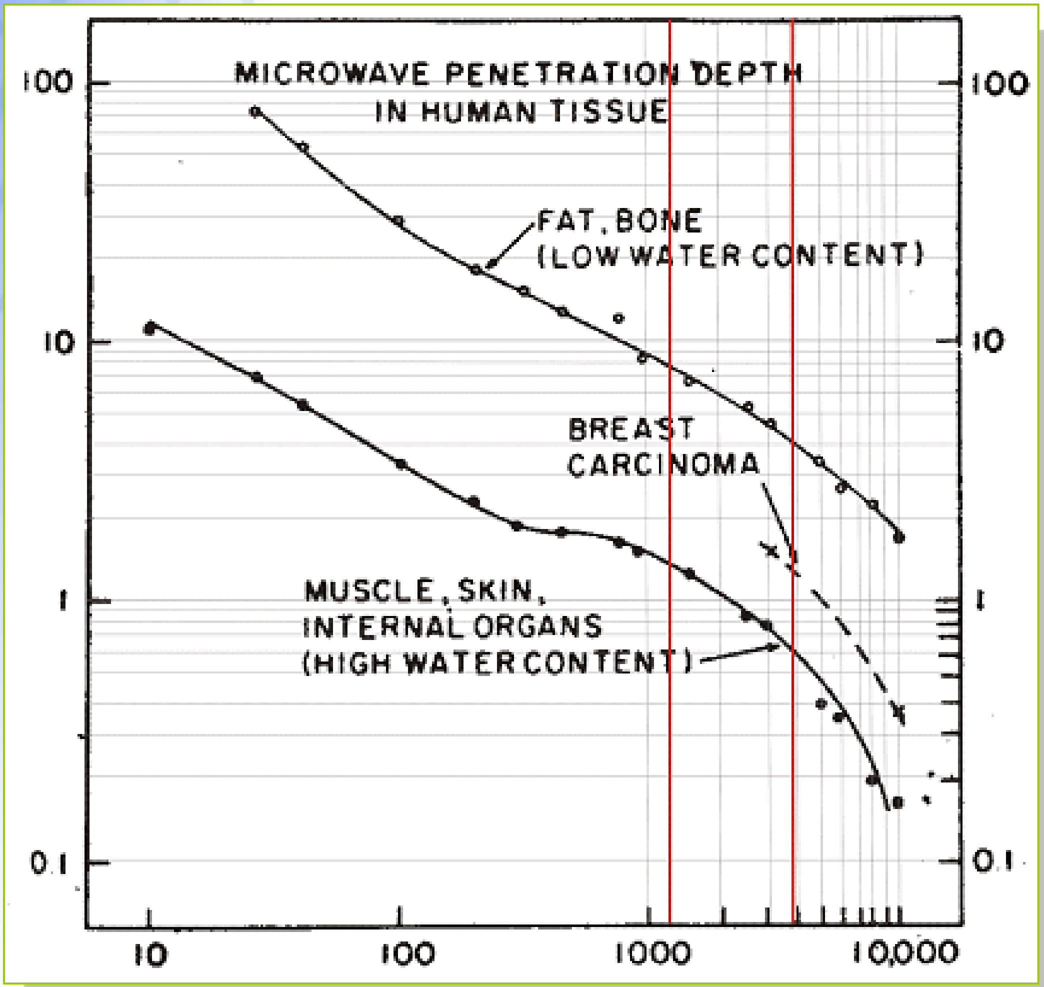
$\overline{E}(r)$ -The Vector of the Electric Field Intensity Induced in Tissue by the Antenna

σ -The Conductivity of the Tissue

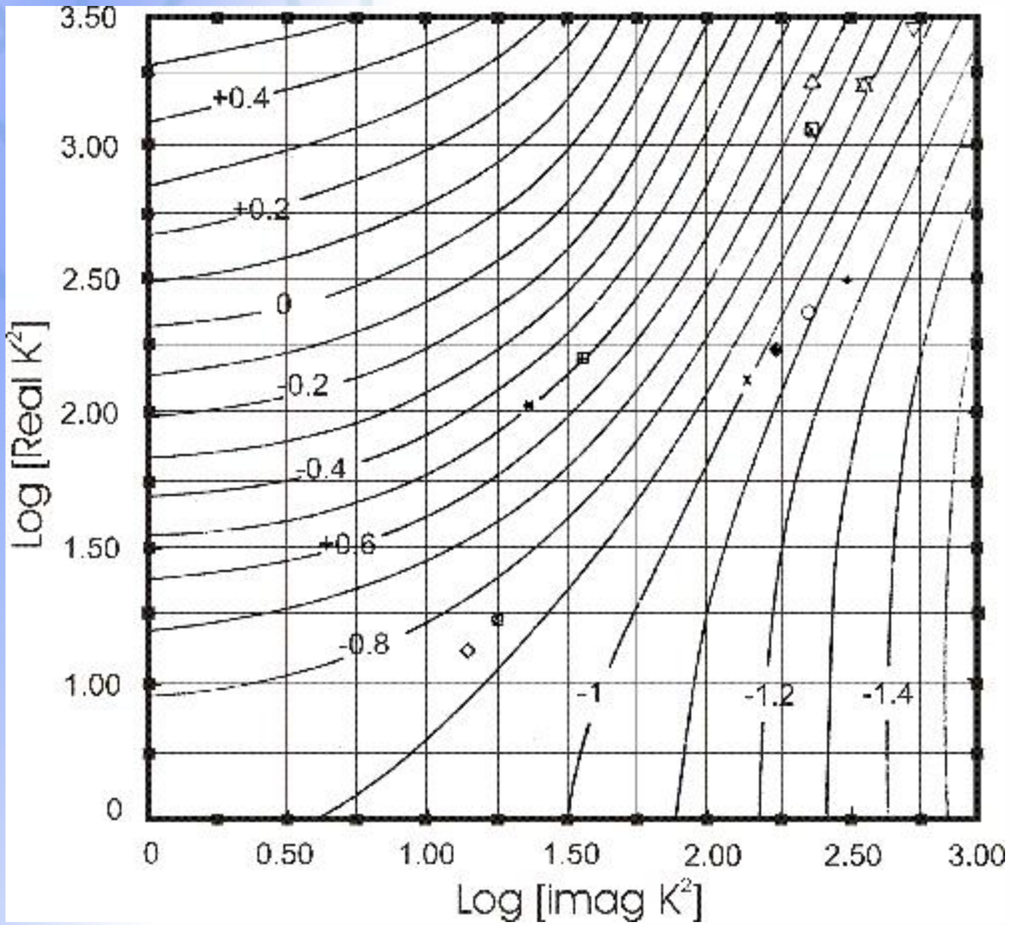
Contradictions in the Literature

Published	Our Experiments
Calculated penetration depth =6.6mm For rectangular waveguide at F=1.15 GHz a=44mm $\varepsilon = 5.5\_\sigma = 0.05$	More then 40mm
Penetration depth do not differ much with the kind of probe	Penetration depth of microstrip probe differs from cylinder waveguide probe substantially
The radiometric temperature increase mainly due skin temperature increase.	Experiments show that sometimes skin temperature is increase and radiometric is decrease.

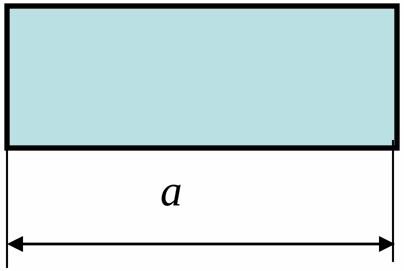
Penetration Depth for Plane Wave



Contour Plot of the Penetration Depth[1]



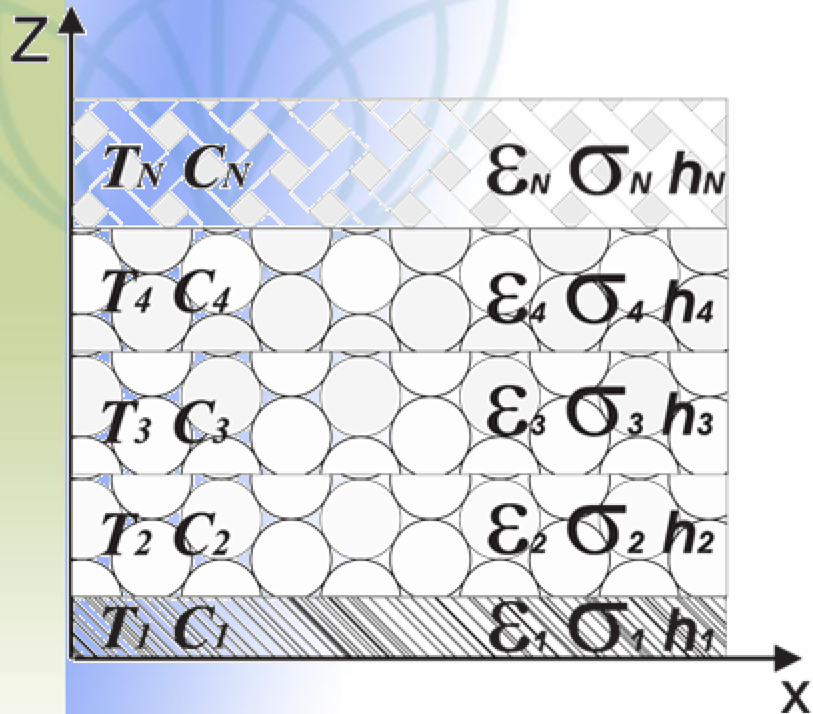
$$K = ka = \omega(\varepsilon_0 \mu_0 \varepsilon)^{\frac{1}{2}} a$$



$$Depth_{\_F=1.15\_a=44mm} = 6.2mm$$

$$Depth_{\_F=3.8\_a=21mm} = 3.4mm$$

Radiometric Temperature for Layer Structure



$$T_{rad} = \sum_{i=1}^{N} T_i * C_i$$

$$C_i = \frac{\sigma_i \int_{V_i} \left|\overline{E}(r)\right|^2 dV}{U}$$

$$U = \sum_{i=1}^{N} \sigma_i \int_{V_i} \left|\overline{E}(r)\right|^2 dV$$

$$D(z) = \sum_{i=1}^{N_z} C_i$$

$$z = \sum_{i=1}^{N_z} h_i$$

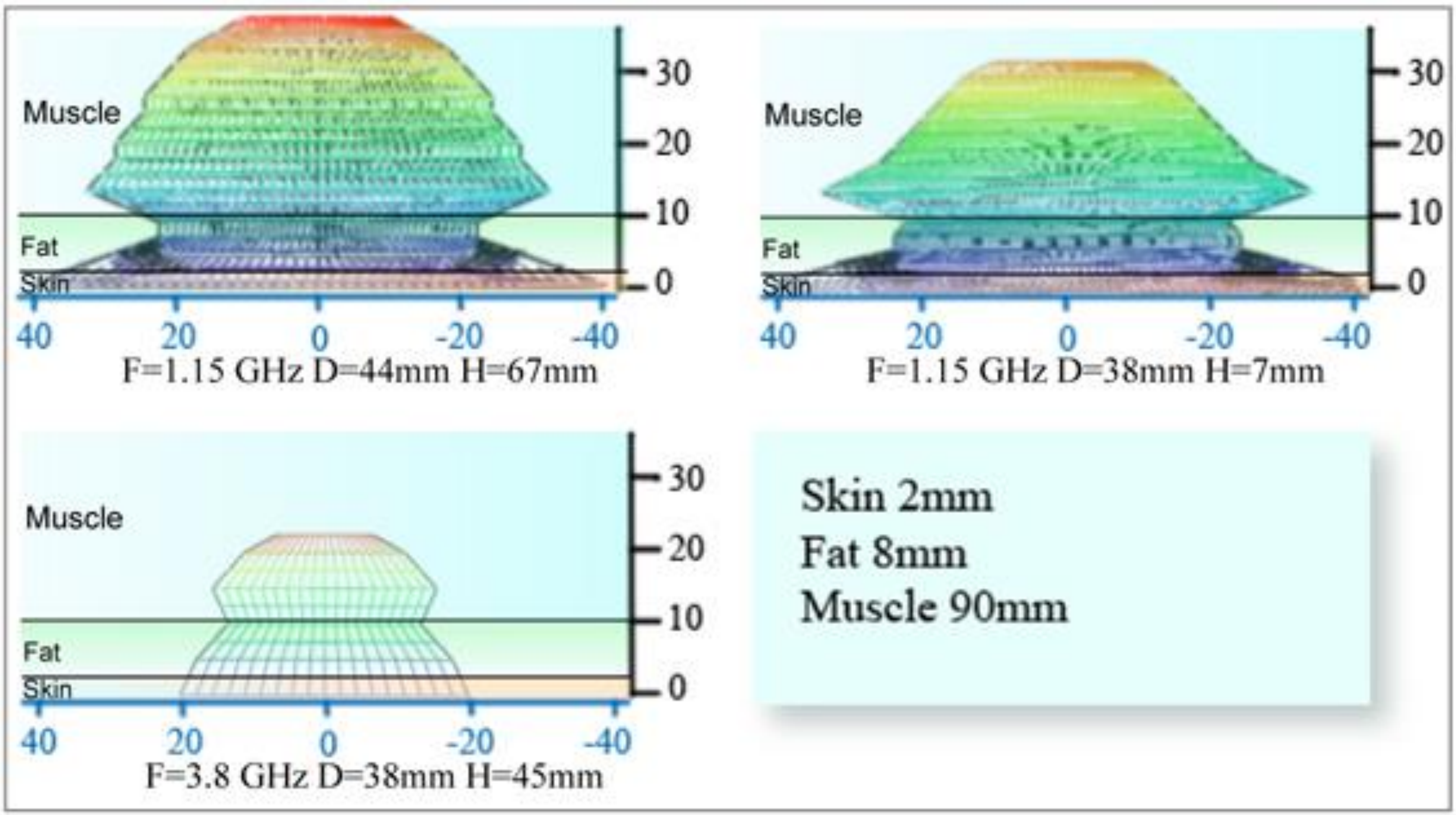
Ci-Weighting Coefficients for Layer Structure

D(z)- Integration Weighting Function for Layer Structure

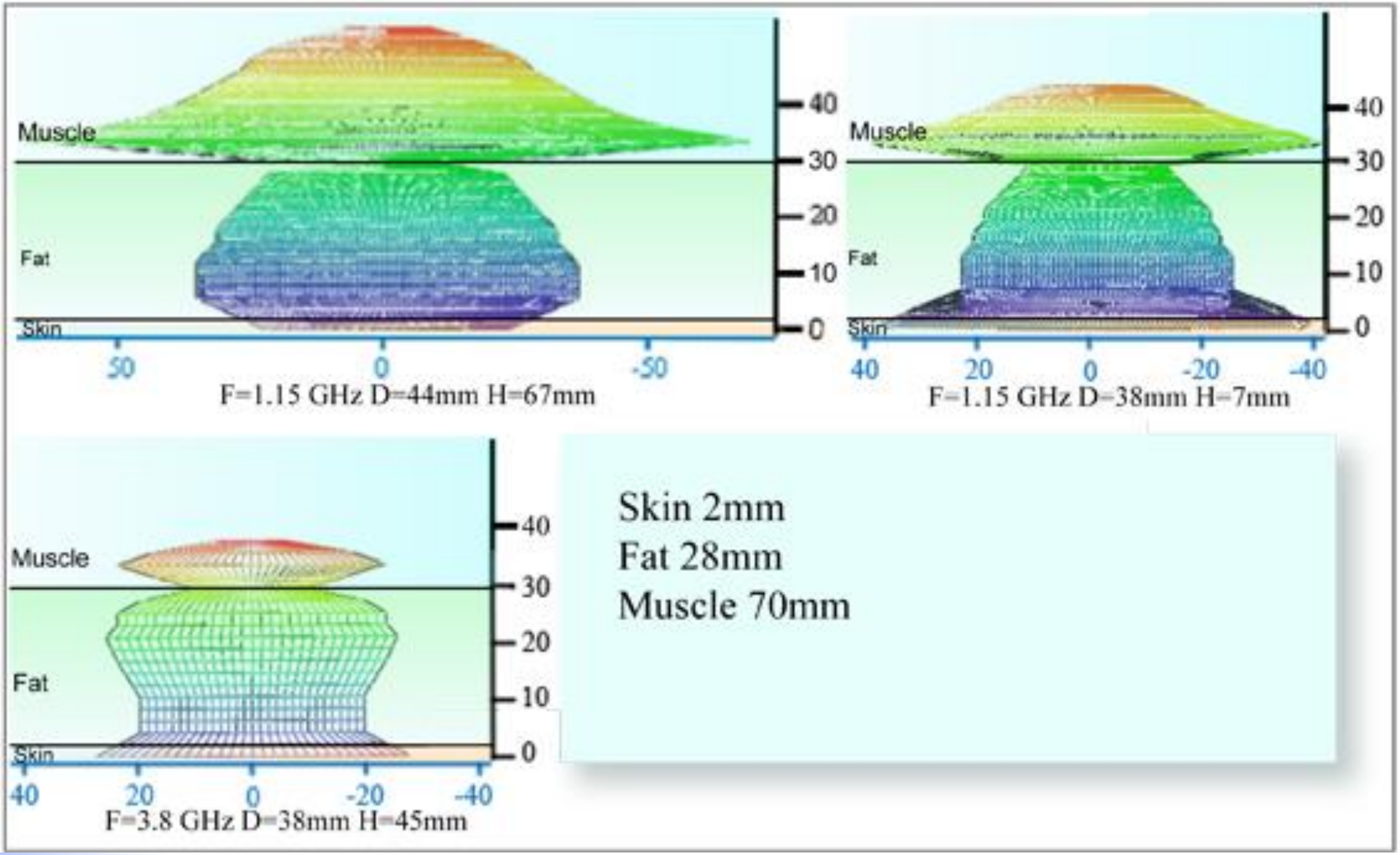
Dielectric Properties of the Tissues

	F=1.15 GHz			F=3.8 GHz		
	Skin	Fat	Muscle	Skin	Fat	Muscle
Dielectric constant ε	55.4	5.5	46	55.4	5.16	46
Conductivity σ (s/m)	1.08	0.055	2.55	2.76	0.31	5.48

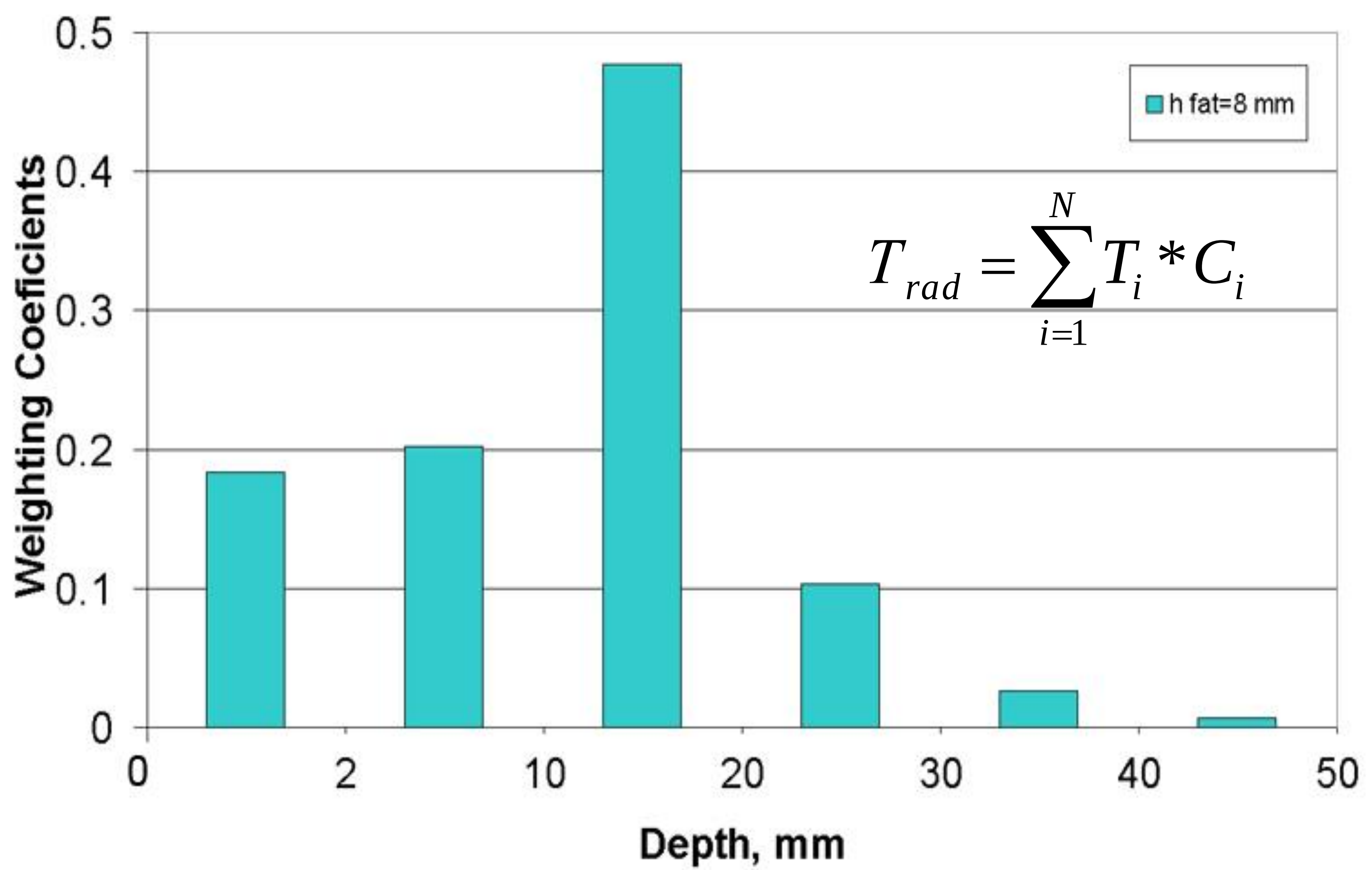
Volume Under Investigation for Different Antennas (Level 85%)



Volume Under Investigation for Different Antennas (Level 85%)

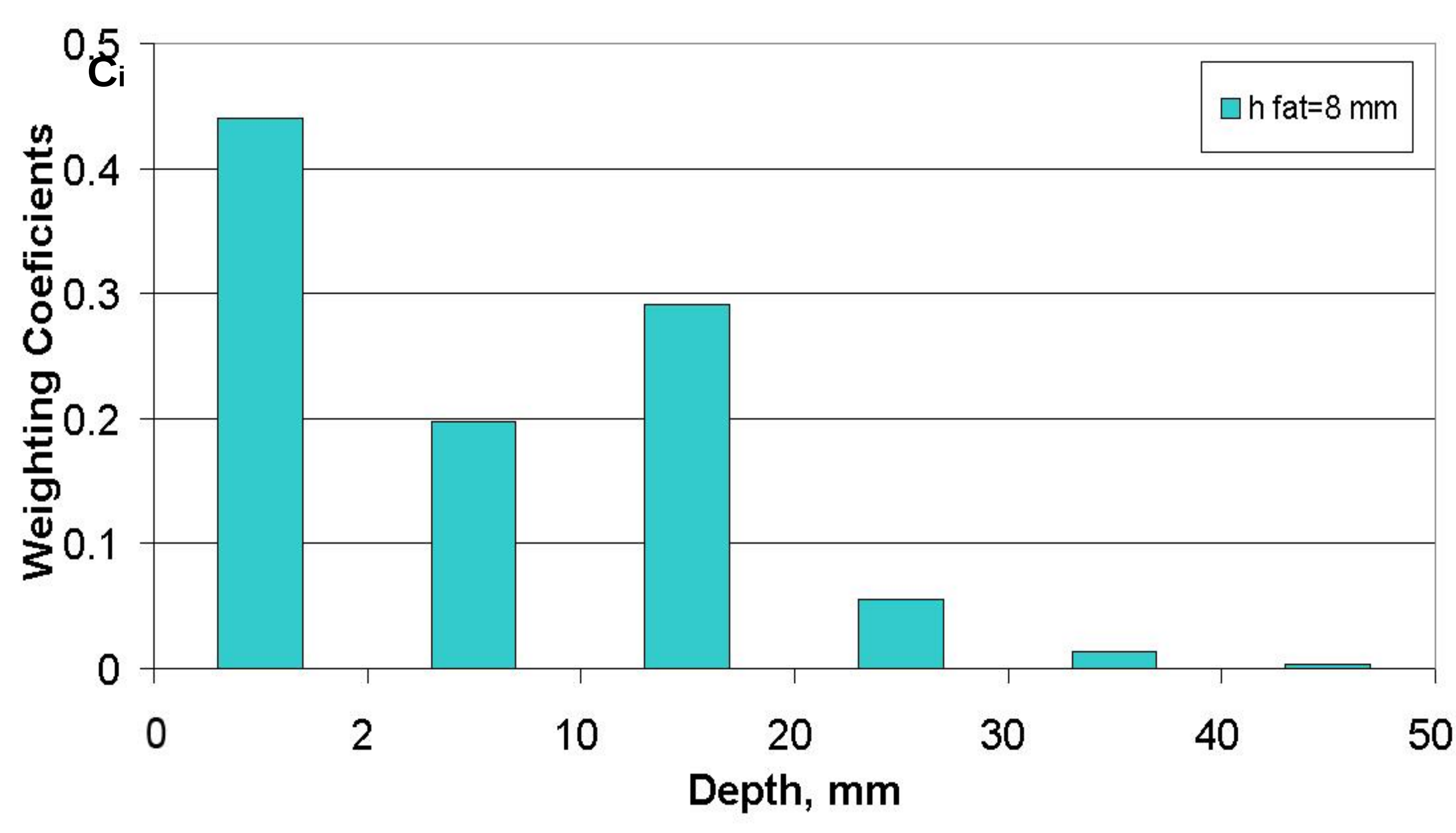


Weighting Coefficients for Antenna F=1.15 GHz D=44mm H=67mm

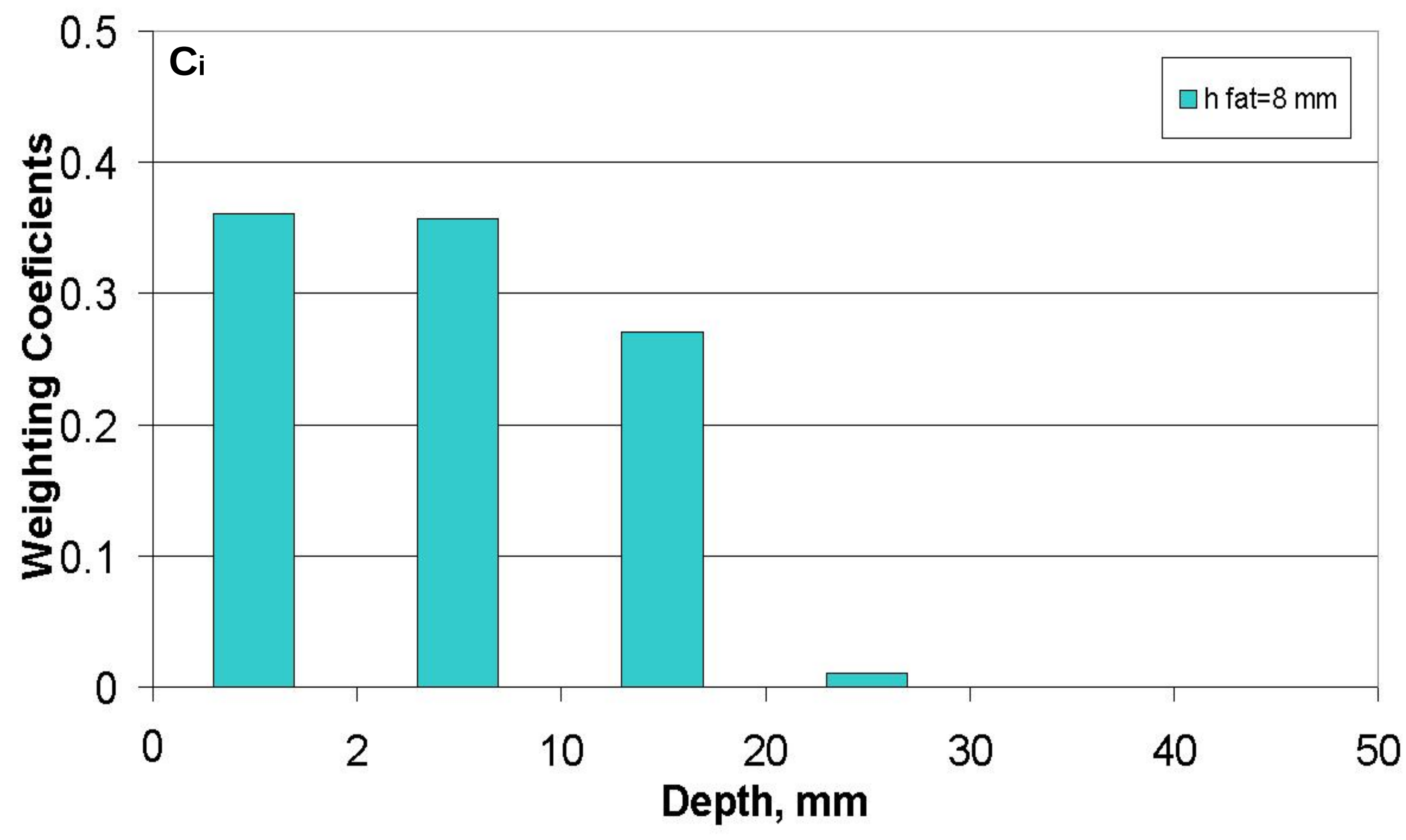


$$T_{rad} = \sum_{i=1}^{N} T_i * C_i$$

Weighting Coefficients for Antenna F=1.15 GHz D=38mm H=7mm

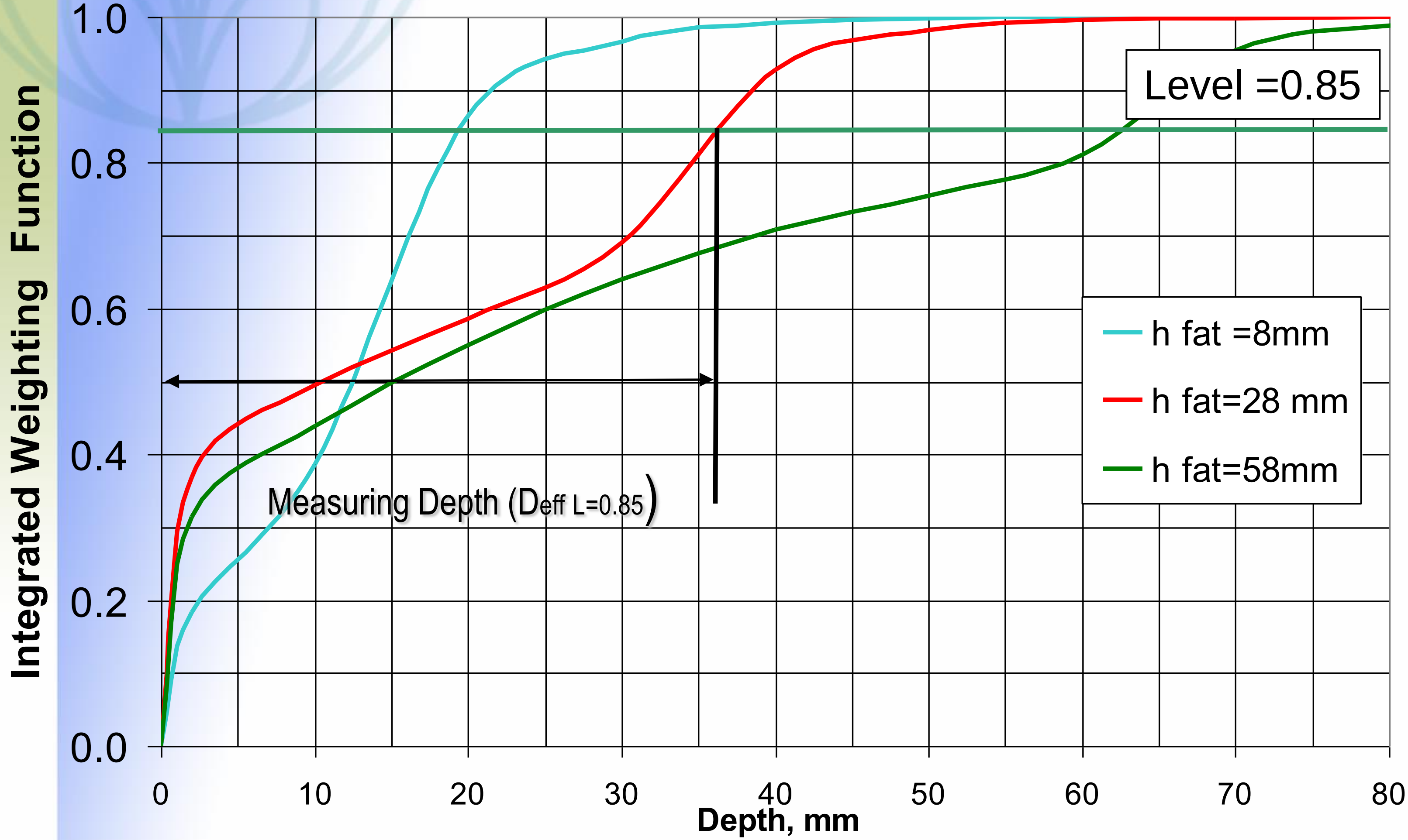


Weighting Coefficients for Antenna F=3.8 GHz D=38mm H=45mm

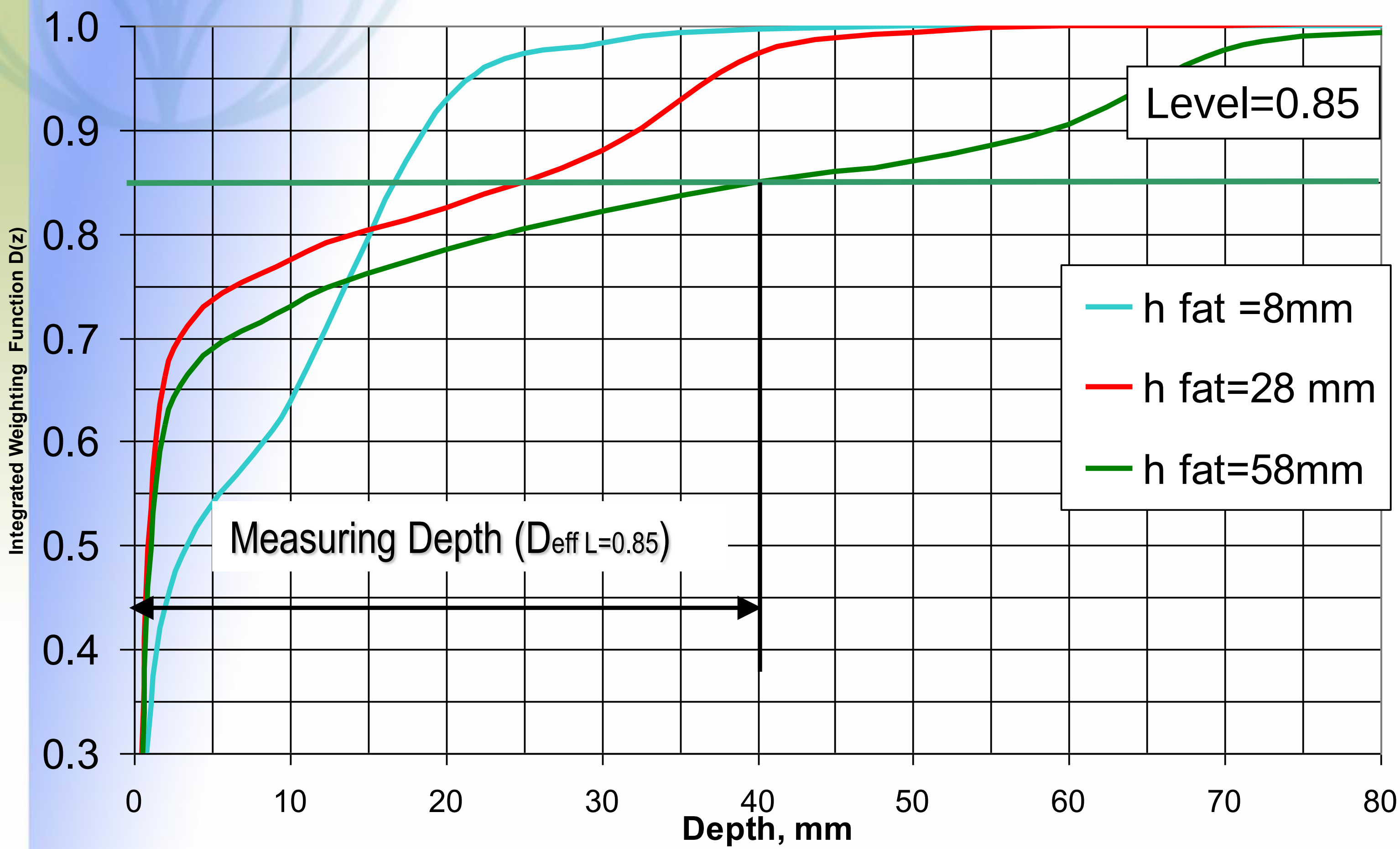


Integrated Weighting Functions
F=1.15 GHz D=44mm H=67mm Antenna

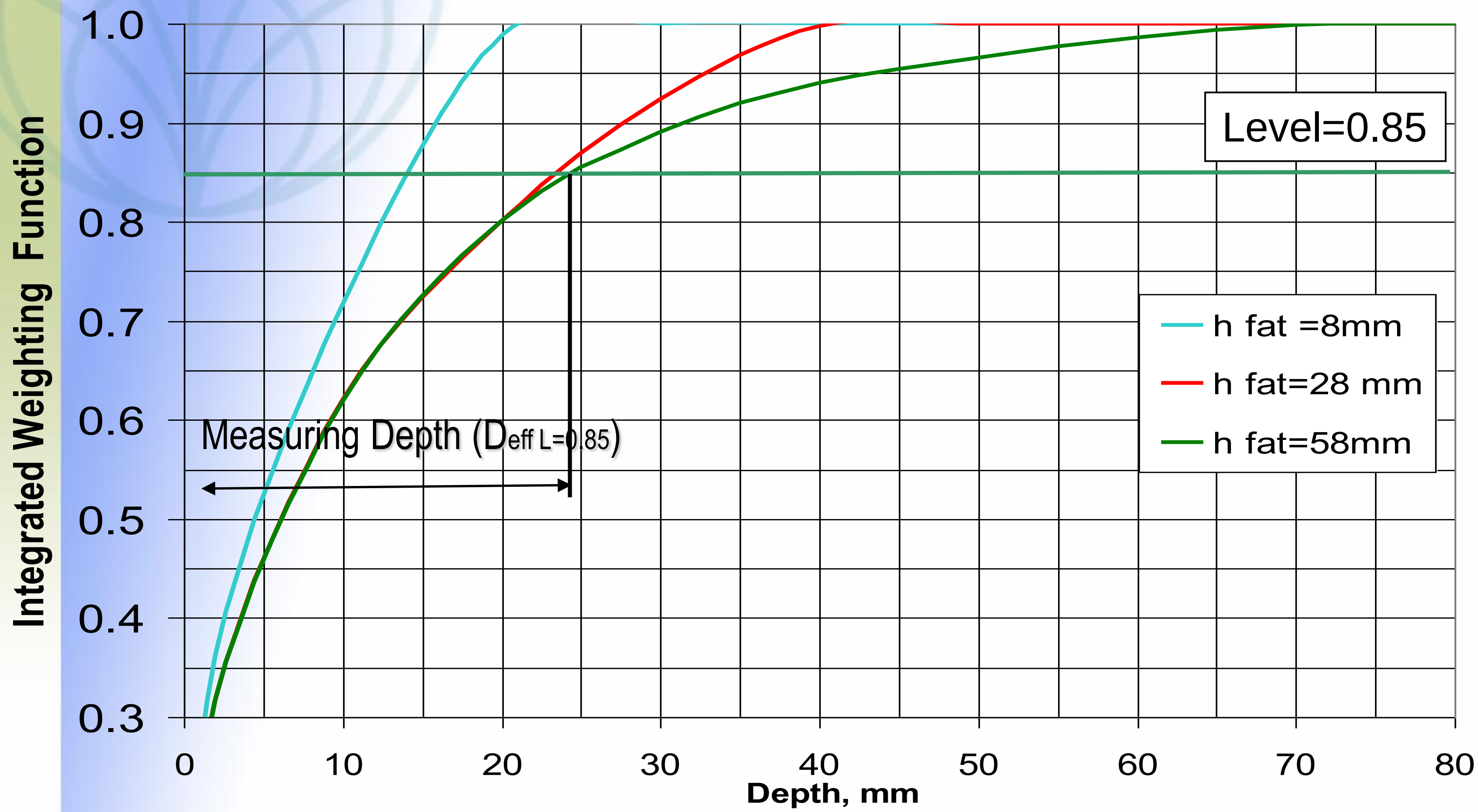
$$D(z) = \sum_{i=1}^{N_z} C_i$$



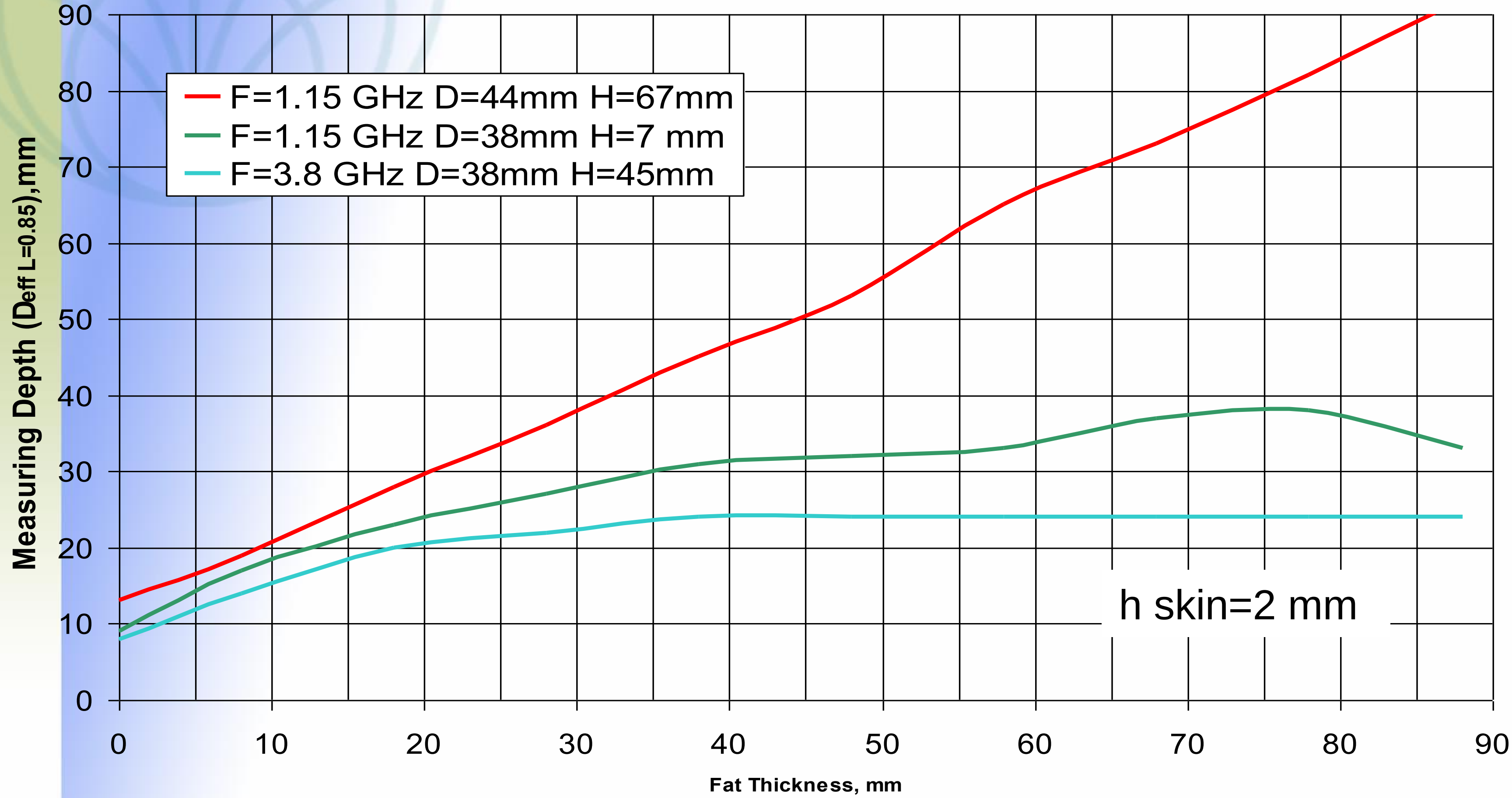
Integrated Weighting Functions
F=1.15 GHz D=38mm H=7mm Antenna



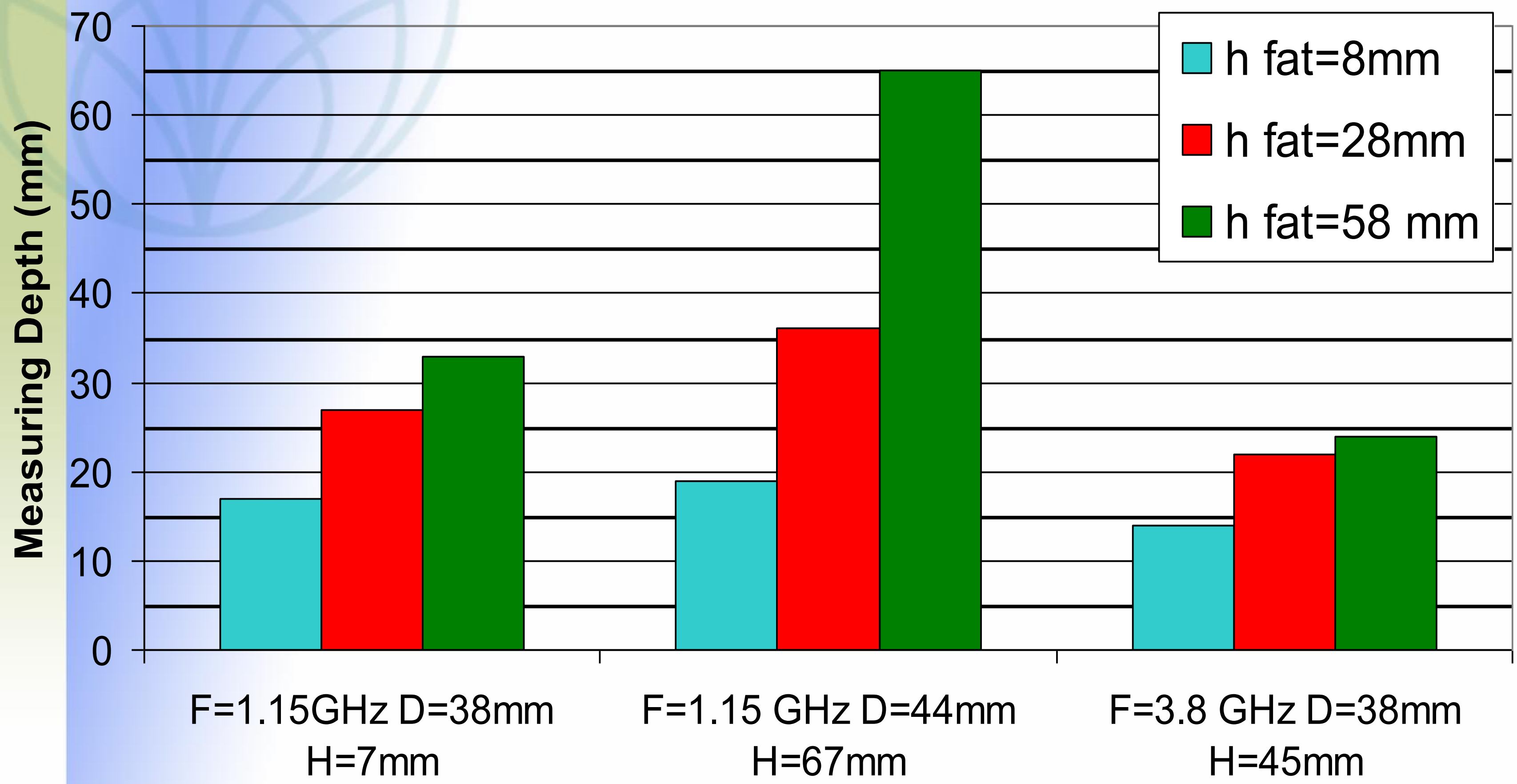
Integrated Weighting Functions
F=3.8 GHz D=38mm H=45mm Antenna



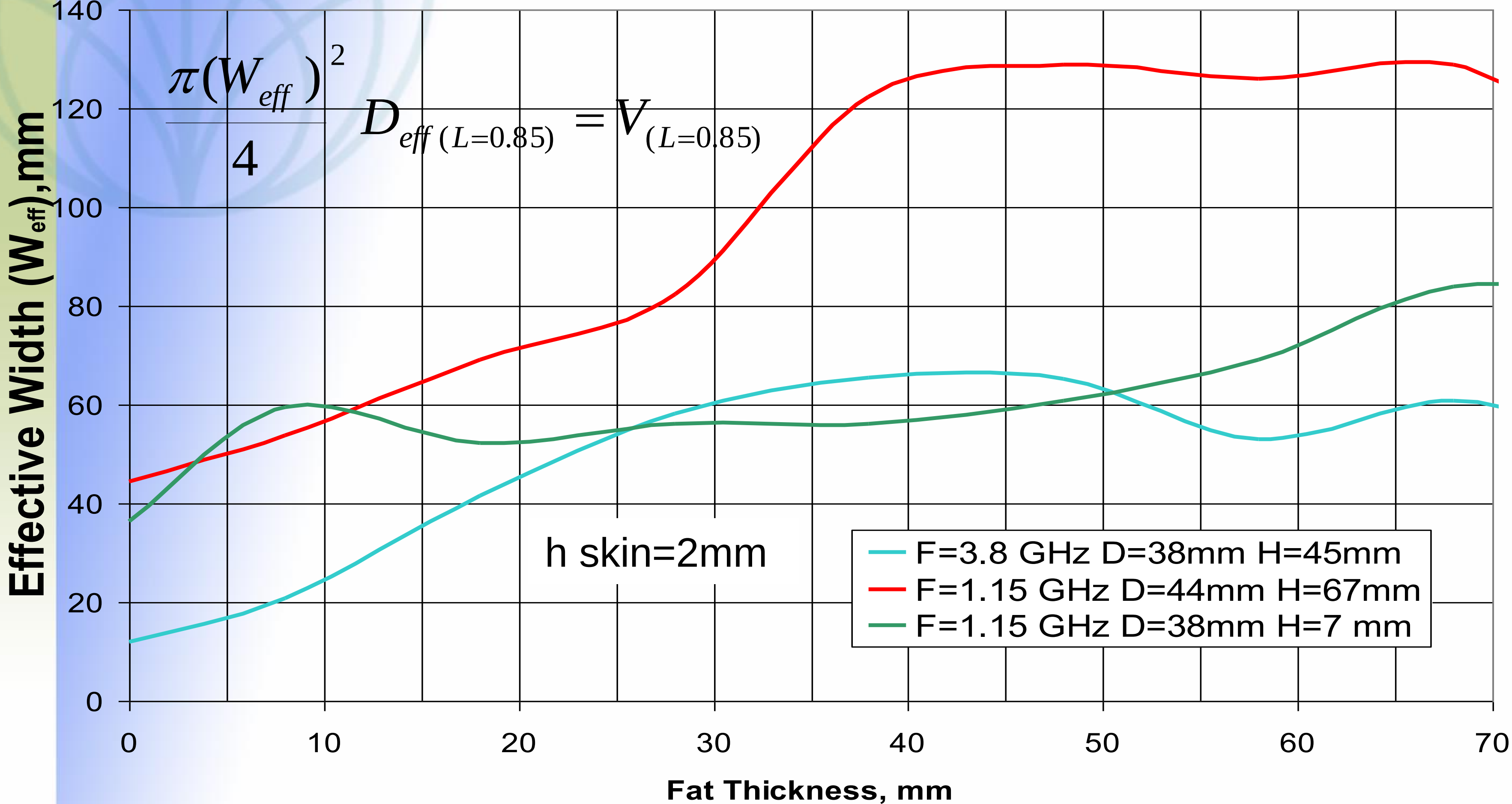
Measuring Depth ($D_{eff\ L=0.85}$) for Different Fat Thickness



Measuring Depth ($D_{eff\ L=0.85}$)



Effective Width for Different Fat Thickness



Temperature Changes During the Cooling of Dorsum