Schmid & Partner Engineering AG
s p e a g
Zeughausstrasse 43, 8004 Zurich, Switzerland
Phone +41 44 245 9700, Fax +41 44 245 9779
info@speag.com, http://www.speag.com

MAINTENANCE OF TISSUE SIMULATING LIQUIDS

1 COMPOSITION OF TISSUE SIMULATING LIQUIDS

Tissue simulating liquids are based on a mixture of water with other components. Target parameters for the permittivity and conductivity of head and body tissue simulating liquids as well as sample recipes are given in the standards (e.g., [1], [2], [3], [4], etc.).

A concentration of at least 40% water should be maintained to achieve the desired permittivity (approx. 80) at an environmental temperature of 22°C. In addition to water, a further component is required to limit the permittivity without increasing the conductivity above the required value. The parameters of the selected component determine the limitations of its useful frequency range.

The following components can be used:

- **Sugar** for frequencies <1 GHz
- **DGBE** Diethylene-Glycol-Monobutyl-Ether, for frequencies from 1 to 2.5 GHz
- **Oil** with emulgators, for frequencies >2.5 GHz

Further, minor additives serve the following purposes:

- **NaCl** to increase the conductivity to the target value
- **Cellulose** to keep the sugar solved
- **Preservative** to prevent the solutions from degrading due to bacterial and fungal growth

During the usage of tissue simulating liquids, given a large surface area exposed to the air and humidity of the laboratory environment, mainly only water evaporates; compared to water, the vapor pressure of all the above listed ingredients is low. Solid ingredients and other additives without high vapor pressure will rarely evaporate. These rather tend to cling to the phantom surface or the edges.

As a result of the water evaporation, the dielectric parameters will change with time towards lower values and need to be corrected to within the required tolerance of 5% from the target values. Add de-ionized water to re-establish the parameters according to the following rules:

- Measure the liquid parameters and calculate the deviation from permittivity and conductivity. Be aware of your measurement uncertainty and the effect of the temperature gradients on your results.
- Calculate the required amount of missing water to obtain the desired parameters. The permittivity can be measured with higher reliability (in the absence of bubbles) and is more greatly affected in most cases. Be aware that the conductivity may also increase.
- Start by adding 50% of the amount required for correction to the liquid and mixing well.
- Repeat the measurement, verify the effect and calculate the figures for further correction.

Note that the parameters will also change with temperature. The temperature gradients of permittivity and conductivity depend both on the liquid type and the frequency and are not treated here. It is assumed that liquid parameters are measured at the same temperature. Storage at below the freezing point is not allowed due to the high water content.

Solid material contaminants like hair, dust, etc. may be filtered out if needed. Before using samples for measurement, make sure the liquid is homogeneous so that it represents the necessary average characteristics. Note that it is also important to homogenize the liquid before returning it into its storage container in order to maintain these average characteristics.

The following subsections contain liquid specific characteristics. The measures described in the Material Safety Data Sheets (MSDS) must be observed. Many liquids are skin irritants and must not be disposed of simply via the sewerage system or into the environment.

2 SUGAR BASED LIQUIDS

Preservative is contained in this type of liquid to suppress bacterial and fungal growth. After storage as well as between periods of usage, the liquid can become inhomogeneous due to the heavier sugar settling at the

bottom and near surfaces. If the liquid begins to become lumpy after a very long storage time, heating and stirring is recommended to re-dissolve the lumps. Otherwise, stirring is sufficient for homogenization. Shaking will lead to air bubbles which may require considerable time to dissipate; foam may need one or more hours to disappear.

The sensitivities of sugar based SPEAG tissue simulating liquids at the frequencies of interest are typically in the following range:

HSL: permittivity 1.0 to 1.6 per % of water, conductivity –0.02 to 0.1 per % of water

MSL: permittivity 0.7 to 1.0 per % of water, conductivity 0 to 0.06 per % of water

Example: Adding 10 g of water to 1 kg (1.0 weight %) of MSL900 liquid is expected to increase the permittivity by 0.9 (from 45.0 to 45.9) and the conductivity by 0.01 (from 1.00 to 1.01).

If it is not possible to correct the liquid solely by adding water, other measures should be taken after verifying their effectiveness on a sample.

- Adding NaCl will mainly increase the conductivity. Permittivity may also be influenced by higher or lower values.
- Adding Sugar will have the inverse effect of adding water. To dissolve the sugar, a long stirring time and preferably elevated temperature is required. Alternatively, it may be easier to leave the liquid in an open phantom for some time during which time water will evaporate.

3 DGBE BASED LIQUIDS

DGBE is easily dissolved in water. Given a DGBE-water mixture, mainly water will evaporate, because DGBE has a lower vapor pressure. For the frequency liquids around 2.5 GHz, no NaCl is contained and should therefore not be added for any corrections.

Evaporated water can be replaced and will mainly increase the permittivity, and to a small extent the conductivity, typically as follows:

HSL: permittivity 0.8 to 1.0 per % of water, conductivity 0 to 0.1 per % of water

MSL: permittivity 0.8 per % of water, conductivity 0 to 0.01 per % of water

Observe the instructions in the MSDS when handling the liquid. Measures should be taken to protect the eyes and skin. DGBE has some characteristics similar to the brake-fluid used in automobiles and should be handled carefully.

4 OIL BASED LIQUIDS

Oil based liquids are an emulsion of a complex mixture of ingredients. Their appearance is dark transparent in most cases. Some liquids (like HSL 5800) can show a non-transparent upper zone with a creamy appearance after some time without stirring. When exposed to air, the upper boundary layer can change its consistency slightly due to the evaporation of water. Before using or handling the liquid, it must therefore be stirred to become entirely homogeneous. An opaque appearance is possible but will not influence the dielectric parameters.

Evaporated water can be replaced and will increase the permittivity, and to a smaller extent the conductivity. Be aware that at high frequencies, the measurement uncertainty tends to increase, especially for the conductivity. Corrections should therefore be made in several steps. Reduction of the water content is only possible by evaporation in a container or phantom with a large surface area exposed to air.

5 REFERENCES

[1] Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), “Additional information for evaluating compliance of mobile and portable devices with FCC limits for human exposure to RF emissions”, June 2001.

[2] IEEE 1528-2003, “IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques”, December 2003

[3] IEC 62209-1, “Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005

[4] IEC 62209-2, “Procedure to determine the Specific Absorption Rate (SAR) in the head and body for 30 MHz to 6 GHz Handheld and Body-Mounted Devices used in close proximity to the Body", draft 2007