Cut-off Tube Design

Microwave power will attenuate as it passes through a circulator waveguide having a diameter less than that which allows the power to propagate freely. This circulator waveguide is commonly called a "cut-off tube" and is used extensively in the design of window screens, ventilation ports and other such openings for microwave cavities. The rate of power attenuation is a function of its wavelength and cut-off tube radius based on the following equation for the attenuation constant α:

$$a = 8.69\sqrt{\left(\frac{2p}{l_c}\right)^2 - \left(\frac{2p}{l}\right)^2}$$ where λ_c equals 3.41 times the tube radius.

The curves below are plotted for ISM frequencies at 915 MHz, 2450 MHz and 5.8 GHz and are used to find the minimum cut-off tube length given the tube diameter and the entering and exiting power densities. The maximum output from industrial equipment and consumer appliances should be limited to 25 mW/cm^2 which yields the common regulatory limit of 1mW/cm^2 when measured at 5 cm from the source. A conservative estimate of the maximum incident power density in a lightly loaded cavity is:

Input = 4 x (microwave power delivered)/(cavity inside surface area)

For example, a perforated metal screen having 1/8″ diameter holes attenuates approximately 250 dB per inch of thickness. When used on a typical microwave oven having 1 kW power input and 1200 in^2 inside surface area, the cut-off tube input power density is 516 mW/cm^2. The total required attenuation *A* is

$$A = 10\log\left(\frac{Input}{Output}\right) = 10\log\left(\frac{516}{25}\right) = 13.1 dB$$

Thus, the minimum screen thickness is 13.1/250 = 0.052 inches. The designer should also consider applying a safety factor wherever appropriate.

Please note that the curves below apply only to empty (air filled) cut-off tubes. Inserting a dielectric material into the tube will increase the length required to achieve the same total attenuation. Furthermore, inserting a metallic object will cause the cut-off tube to act as a coaxial transmission line which propagates the microwave energy with very little attenuation. Extreme caution must be exercised in such cases.

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