General Guidelines for the Configuration and Selection of Microwave Generators and Waveguide Components

Most industrial microwave heating systems consist of three basic elements, a microwave generator to produce microwave power, waveguide components to transmit microwave energy, and a load to be heated. Microwave systems are available in several different configurations each offering performance characteristics designed for specific heating applications. Engineers are presented with a wide variety of component and configuration choices, and the information presented in this document will provide a general guideline to assist the engineer in configuring a microwave generator system.

A typical microwave system is illustrated in Figure 1 below:

![Figure 1. Typical microwave generator system](image)

**Microwave Generators**

Microwave generators are designed to provide stable and controllable microwave power and are available in two standard configurations: Integrated Microwave Generators or Modular Microwave Systems. An integrated microwave system consists of all generator subsystems and subcomponents contained within one cabinet, while modular microwave systems are supplied as separate building block components (power supply, magnetron head, and cable assembly). Whether you decide to use an integrated or modular system, both generators will have the following common subcomponents.
Magnetron Head

The magnetron head consists of a magnetron, waveguide launcher, filament transformer and both the electrical and mechanical systems required to generate and propagate the microwave energy. All system sub components have been designed to offer the highest level of performance, stability, and system efficiency. Microwave heads can be supplied as air or water-cooled units with the determining factor for selecting either option based upon operating environment and location constraints.

Power Supply

The power supply provides the necessary voltage and current to power the magnetron, and depending on its sophistication, provides remote and/or a user interface for system control. The three most common power supply types used in microwave heating applications include: switch-mode, conventional / inductive (L-C), and pulse. Power supplies are primarily application dependent, but cost is often a considerable factor.

- Switch-mode power supplies convert an AC input voltage to a low ripple adjustable DC current. The primary advantages of switch-mode power supplies are their compact size, stability and low ripple thus producing a high quality output spectrum.
- Conventional/Inductive (L-C) power supplies are offered in different styles, but are similar in construction. They include transformers (high voltage and filament), capacitor(s), and diode(s). The most common types include full-wave doubler, half-wave doubler and full-wave rectified. The advantages of an inductive power supply are their robust build quality and the relative cost compared to switch-mode or pulse power supplies. Another benefit is their ability to operate in generally poor environmental conditions.
- Pulse power supplies represent the latest technology for microwave power supplies. As their name implies, they are able to operate a magnetron in pulse mode, which achieves a higher peak output powers within a specified time period. Many pulse power supplies also have the capability to operate the magnetron in “CW” or continuous mode as well.

Waveguide Components

It may be necessary to add additional waveguide components to the transmission line to for a variety of reasons. The most common waveguide components are described below and their location in the transmission line is illustrated in Figure 1 above.

Isolators/Circulators

A circulator is defined as a 3-port device utilizing ferrite technology (magnets) to selectively direct microwave energy to a specific port based on the direction of wave propagation. An isolator is a circulator with a “dummy load” attached to one port. An isolator serves two main functions in a microwave circuit:

1) It protects the magnetron from reflected microwave energy.
2) Provides the magnetron with a matched-load for efficient generation of microwave energy.
Circulators/Isolators are most commonly used in microwave systems as low as 2.0kW but are mandatory at systems with power ratings of 6kW and above. Isolators are typically located closest to the magnetron head/launcher.

**Directional Couplers**

A directional coupler is defined as a device used to couple power from the waveguide system at a reduced value to facilitate equipment interface for frequency, power, or other system measurements.

Directional couplers are most commonly used to measure forward and/or reflected energy. Their output is an attenuated RF signal that can be measured in a few different ways. One such way to measure the sampled energy is to use a power meter and power sensor attached to the measuring port of the directional coupler. The power sensor, which is calibrated for a specific frequency range and attenuation level, interprets the signal present at the couplers output and sends this information to the power meter for display. Another common measuring method is to use a detector diode attached to the measuring port of the coupler. The diode outputs a voltage proportional to the sampled energy with the output power determined from the diodes characteristic curve.

**Tuners**

A tuner is defined as a mechanical waveguide component used for matching of the load impedance to that of the source, thereby reducing reflected power and maximizing the coupling power to the load/product. A tuner functions as an impedance matching device by manipulating the electromagnetic fields inside the waveguide by adjusting the depth of metal stubs placed at specific guide lengths. These stubs change the capacitance thereby altering the transmitted wave property, which has the effect of “tuning” the microwave circuit.

Tuners are classified as either being “manual”, in which the stubs are manually adjusted into the waveguide, or as “automatic”, in which the stubs are attached to a motor that automatically adjust their depth into the waveguide.

**Waveguide**

Waveguide size depends on operating frequency, power rating and cost. Table 1 lists the various waveguide sizes commonly used in microwave systems. The ISM (industrial, scientific and medical) frequencies most commonly used for microwave heating include 2450 MHz (S band), 915/896/922 MHz (L band) and 5.8GHz (C band).

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>Frequency Range</th>
<th>Waveguide Size</th>
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<tbody>
<tr>
<td>L</td>
<td>1 - 2 GHz</td>
<td>WR975 R9</td>
</tr>
<tr>
<td>S</td>
<td>2 - 4 GHz</td>
<td>WR430 R22</td>
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<td></td>
<td></td>
<td>WR340 R26</td>
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<td></td>
<td></td>
<td>WR284 R32</td>
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<tr>
<td>C</td>
<td>4 - 8 GHz</td>
<td>WR159 R58</td>
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Although there is no published standard waveguide size for 2450MHz system, WR284 is common for applications up to 6kW, WR340 for power levels up to 10kW, and WR430 for power levels up to 30kW. Standard flange dimensions accompany each waveguide size with a “flat” flange being the most popular type followed by a “choke” flange, which is more common in communication applications.

Waveguide Material
Waveguide is typically constructed from one of three materials: aluminum, copper and stainless steel. Aluminum is the most commonly used material and chosen primarily for its overall performance characteristics and low cost. Copper is used in specialty applications where conductivity and heat loss are the main concerns. Stainless steel is often used in food processing systems and pharmaceutical applications, which sanitation requirements are present.

Microwave System Design
Designing a microwave system begins by determining the following two main system components, the microwave source and load/cavity.

Microwave Source Considerations:
1) Frequency
2) Output Power Level
3) Frequency Stability/Output Ripple
4) Form Factor
5) Control
6) Cost

Microwave Load Considerations
1) Cavity Type
   a. Multi-mode
   b. Resonant
2) Applicator Type

It should be noted that a variety of factors can influence the design and subsequent selection of the correct microwave generator for use with a particular application. Richardson Electronics has extensive experience in the design, integration, and production of complete microwave generator systems, magnetron heads, power supplies and waveguide components. Our microwave and system experts are prepared to assist you in determining the best microwave system and components for your application.
About Richardson Electronics

Founded in 1947, Richardson Electronics, Ltd. has a rich and unique history of engineering solutions and distributing electronic components for the global electron device, industrial power conversion and display systems markets. Headquartered outside Chicago, in La Fox, Illinois, Richardson Electronics serves clients throughout the world’s major economic regions. The company distributes and manufactures high-power, high-frequency electronic components, sub-assemblies and sub-systems for many diverse markets, including Semiconductor Equipment, Laser, Medical, Marine, Avionics, Microwave & RF Industrial Heating, Radio & TV Broadcasting, Radar and Communication.

The CW Microwave Division within Richardson Electronics offers a wide range of products including complete turn-key microwave generators, magnetron heads, power supplies, magnetrons, waveguide components and RF coils. Our Engineered Solutions are driven by our customer needs, and we add value through design-in support, systems integration, prototype design and manufacturing and testing. We employ technical field engineers to work with our customer to understand their requirements and identify possible solutions through new and existing products.