

## **App Note 009 -**

# **Waveguide Insights: Understanding Rectangular and Double-Ridge Designs for Enhanced RF Systems**

### **Overview:**

This App-Note provides a thorough examination of rectangular and double-ridge waveguides, highlighting their design, operating principles, advantages, and applications. It details specifications and power-handling considerations essential for RF systems. Waveguides are crucial in microwave engineering, offering low-loss, high-efficiency transmission for communications, radar, EMC/EMI, and scientific applications. Key topics such as cutoff frequencies, material choices, and power management are explored to offer a comprehensive overview of rectangular and double-ridge waveguides.

### **Rectangular waveguides:**

Rectangular waveguides are structures used for transmitting electromagnetic waves, particularly at microwave frequencies. They guide waves in a specific direction, often for purposes such as communications, radar, or other high-frequency applications.

### **Dimensions and Design:**

- **Dimensions:** The dimensions of rectangular waveguides are critical and are typically denoted by the "WR" number, indicating the waveguide's width in inches. For instance, a WR90 waveguide has an inner width of 0.90 inches.
- **Materials:** Waveguides are commonly made of aluminum, brass, copper, or other metals with low resistivity. Poor conductivity metals can also be used if the interior walls are plated, often with silver, to optimize performance and minimize insertion loss. Millimeter waveguides for frequencies >18 GHz are typically silver-plated to ensure minimal loss.

### **Operating Principle:**

- **Mode of Operation:** Rectangular waveguides support various propagation modes, with the dominant mode being TE<sub>10</sub> (Transverse Electric). This mode has the lowest cutoff frequency.
- **Cutoff Frequency:** Each waveguide has a cutoff frequency below which signal transmission becomes inefficient, determined by the waveguide's dimensions.

### **Advantages:**

- **Low Loss:** Rectangular waveguides exhibit low signal loss compared to other transmission methods, making them efficient for long distances.
- **High Power Handling:** They can handle high power levels, ideal for various applications.

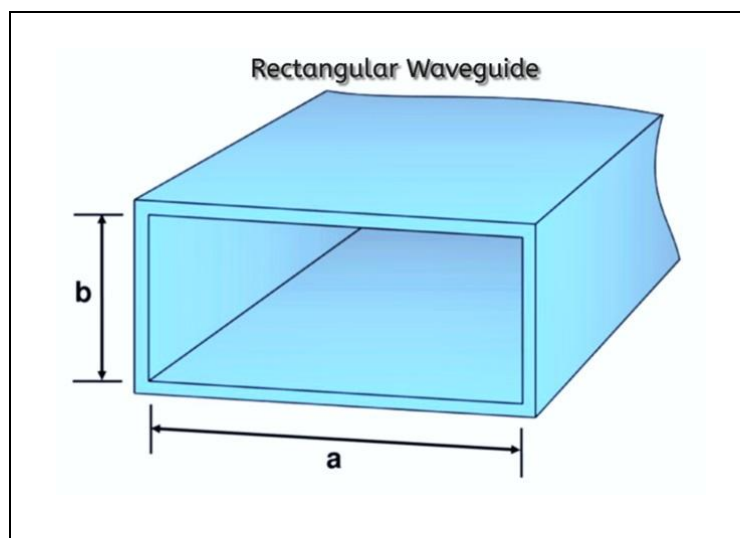
### **Applications:**

- **Communication Systems:** Used in microwave systems like satellite communications, terrestrial microwave links, and EMC/EMI testing.
- **Radar Systems:** Integral components for transmitting and receiving high-frequency signals.
- **Scientific Instruments:** Applied in instruments requiring precise microwave frequency transmission.

In summary, rectangular waveguides are essential components in the field of microwave engineering, providing efficient and reliable transmission of high-frequency signals.

## Standard Rectangular Waveguide:

Waveguide Size (WR)			Freq. Range	Freq. Cut-off-lo	Freq. Cut-off-hi	CW Avg. Power Rating	Peak Power Rating	Waveguide Outside Dimensions	Frequency Band Designation
WR	U.S. Mil.	British Mil.	GHz	GHz (TE10)	GHz (TE20)	KW	KW	mm (w x h)	
WR975	RG204	WG4	0.75-1.12	0.60	1.21	>200.0	>50000	247.65 x 123.82	P
WR770	RG205	WG5	0.96-1.45	0.76	1.53	>200.0	>45000	195.58 x 97.79	L
WR650	RG103	WG6	1.12-1.70	0.91	1.82	>200.0	41340	165.10 x 82.55	L
WR510	NA	WG7	1.45-2.20	1.15	2.31	152.0	26190	129.54 x 64.77	L
WR430	RG105	WG8	1.70-2.60	1.37	2.74	95.0	18230	109.22 x 54.61	LS
WR340	RG113	WG9A	2.20-3.30	1.73	3.47	58.5	11870	86.36 x 43.18	S
WR284	RG75	WG10	2.60-3.95	2.07	4.15	45.0	7650	72.14 x 34.04	S
WR229	RG341	WG11A	3.30-4.90	2.57	5.15	30.0	5480	58.17 x 28.96	E
WR187	RG95	WG12	3.95-5.85	3.15	6.30	18.0	3300	50.80 x 25.40	G
WR159	RG344	WG13	4.90-7.05	3.71	7.42	15.0	2790	40.39 x 20.19	F
WR137	RG106	WG14	5.85-8.20	4.30	8.60	10.0	1980	38.10 x 19.10	C
WR112	RG68	WG15	7.05-10.0	5.26	10.51	6.0	1280	28.45 x 14.22	H
WR90	RG67	WG16	8.20-12.4	6.56	13.11	3.0	760	25.40 x 12.70	X
WR75	RG347	WG17	10.0-15.0	7.87	15.73	2.8	620	19.05 x 9.53	Xs
WR62	RG349	WG18	12.4-18.0	9.49	18.97	1.8	460	17.80 x 9.90	Ku
WR51	RG351	WG19	15.0-22.0	11.6	23.14	1.2	310	12.95 x 6.48	K
WR42	RG121	WG20	18.0-26.5	14.1	28.10	>1.0	170	12.70 x 6.40	K
WR34	RG354	WG21	20.0-33.0	17.4	34.71	>0.8	140	8.64 x 4.32	K/Ka
WR28	RG271	WG22	26.5-40.0	21.1	42.15	>0.7	100	9.10 x 5.60	Ka
WR22	RG97	WG23	33.0-50.0	26.4	52.69	>0.6	60	5.59 x 2.79	Q
WR19	RG49	WG24	40.0-60.0	31.4	62.78	>0.6	50	6.80 x 4.40	U
WR15	RG98	WG25	50.0-75.0	39.9	79.74	>0.5	>3.0	3.81 x 1.91	V
WR12	RG99	WG26	60.0-90.0	48.4	96.74	>0.5	>1.6	5.10 x 3.60	E
WR10	RG90	WG27	75.0-110.0	59.0	118.00	>0.5	>1.6	2.54 x 1.27	W
WR8	RG138	WG28	90.0-140.0	73.8	147.53	>0.4	>1.2	2.032 x 1.016	F
WR7	RG136	WG29	110-170	90.8	181.50	>0.4	>1.2	1.778 x 0.889	D
WR4	RG137	WG31	170-260	137.24	274.48	>0.3	>1.0	1.016 x 0.508	G
WR3	RG139	WG32	220-325	173.57	347.14	>0.3	>1.0	0.762 x 0.381	J



### Double-Ridge Waveguides:

A double-ridge waveguide provides a wider operational bandwidth compared to standard waveguide at the cost of higher insertion loss and lower power handling. The "D" in WRD stands for double-ridge. It features two ridges that protrude into the center of the waveguide, parallel to the short wall. These ridges help to increase the electric field (E-field) within the waveguide, enhancing its performance.

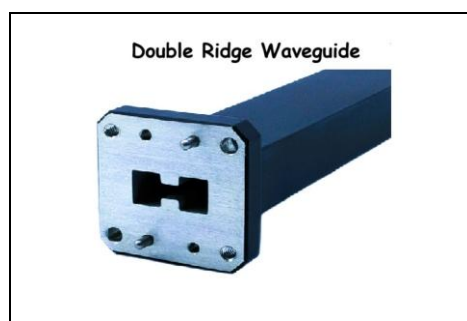
### Key Characteristics:

- **Increased Bandwidth:** The double-ridge design supports a wider frequency range, ideal for applications requiring broad bandwidth.
- **Lower Cutoff Frequency:** Compared to a standard rectangular waveguide of the same outer dimensions, the double-ridge waveguide has a lower cutoff frequency for its fundamental mode.
- **Compact Design:** The double-ridge waveguide can achieve compact designs while maintaining high performance.

### Applications:

- **Microwave Communications:** Used in systems where wide bandwidth and low loss are essential.
- **Radar Systems:** Suitable for high-frequency radar applications.
- **Scientific Instruments:** Employed in various scientific and research equipment requiring precise microwave transmission.
- **EMC testing applications:** Electromagnetic Compatibility (EMC) testing ensures that electronic devices operate without causing or being affected by unwanted electromagnetic interference (EMI).

Waveguide Size (WRD)		Freq. Range (GHz)	Freq. Cut-off-lo	Freq. Cut-off-hi	CW Avg. Power Rating	Peak Power Rating	Waveguide Outside Dimensions	Frequency Band Designation
WRD	U.S. Mil. (Alum) Mil-W-23351-	GHz	GHz (TE10)	GHz (TE20)	KW @1atm.	KW @1atm.	mm (w x h)	
WRD840	23351-4-017	0.84-2.0	0.708	2.08	169.0	1620.0	223.5 x 111.7	L
WRD150	23351-4-021	1.50-3.6	1.26	3.72	43.9	512.0	91.82 x 44.8	LS
WRD200	23351-4-025	2.0-4.8	1.69	4.92	50.0	284.0	101.6 x 177.8	SC
WRD250	NA	2.5-7.8	2.09	8.25	24.0	120.0	63.5 x 127.0	EH
WRD350	23351-4-029	3.5-8.2	2.96	8.61	18.0	92.2	76.2 x 127.0	C
WRD475	23351-4-033	4.75-11.0	4.02	11.61	8.0	85.0	101.6 x 177.8	CX
WRD500	23351-2-025	5.0-18.0	4.22	18.38	4.0	15.0	127.0 x 177.8	CJ
WRD580	NA	5.8-16.0	5.07	16.68	5.2	32.0	88.9 x 177.8	GJ
WRD650	NA	6.0-18.0	5.49	18.29	4.0	25.0	88.9 x 177.8	HJ
WRD750	23351-4-037	7.5-18.0	6.35	18.45	4.8	24.0	88.9 x 177.8	IJ
WRD110	23351-4-041	11.0-26.5	9.32	27.05	1.4	12.0	50.8 x 127.0	J
WRD180	23351-4-045	18.0-40.0	15.24	44.24	0.8	5.0	50.8 x 127.0	K



### Power Handling:

Power handling in RF systems is indeed a complex but crucial topic. It's all about ensuring that components can withstand the power they encounter without being damaged.

Let us break down some key points!

### Two Main Limitations:

#### 1. Average Power-

- **Heating Effects:** When hardware is subjected to high average power, it can overheat, leading to damage. Effective heat-sinks help mitigate this by transferring heat away from the components.

#### 2. Peak Power-

- **Breakdown Effects (Arcing):** High peak power can cause electrical breakdown or arcing. This is where the voltage exceeds the air's ionization threshold, causing a spark.

### Factors to Consider:

#### 1. Average Power-

- **Heat Management:** The combined heat from RF and DC power must be dissipated effectively. The quality of heat sinks plays a significant role here.

#### 2. Peak Power-

- **Voltage Limits:** It's crucial to manage the maximum voltage from RF and DC power to prevent breakdowns. The breakdown voltage, about 3,000,000 volts/meter at sea level, is influenced by altitude and gap size but not frequency.

### Complex Analysis:

- ✚ **Component Qualification:** Ensuring connectors, cables, couplers, antennas, and other components are properly sized for high-power transmission lines is essential. This involves rigorous analysis to prevent failures.

### Summary Statement:

This document provides an in-depth overview of rectangular and double-ridge waveguides, emphasizing their design, operating principles, advantages, and applications. It also includes detailed tables of standard and double-ridge waveguide specifications and power-handling considerations for RF systems. The content highlights the critical role waveguides play in microwave engineering, offering low-loss, high-efficiency transmission for communications, radar, EMC/EMI and scientific applications. Key aspects like cutoff frequencies, material choices, and power management ensure reliable and effective operation across various frequency bands.

Understanding these limitations and factors, you can better protect your expensive equipment and ensure efficient and safe operation of your RF systems.