

Section 16

Short Slot Hybrids

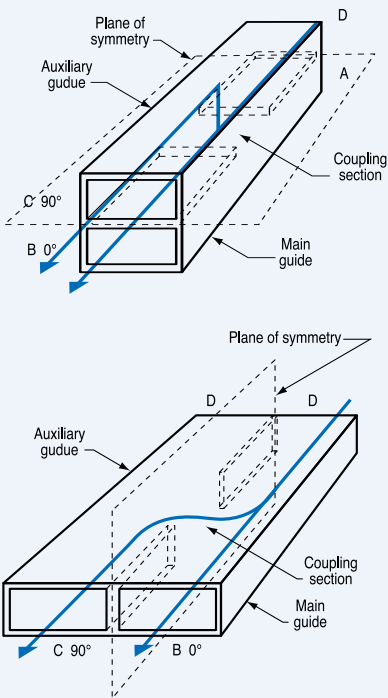


FIGURE 1 – COUPLER TERMINOLOGY

Coupling = Ratio A to C
 Balance = Ratio B to C
 Directivity = Ratio C to D
 Isolation = Ratio A to D
 Isolation = Coupling + Directivity

PHASE DIFFERENCE AT OUTPUTS

Sidewall C lags B by 90°
 Topwall C leads B by 90°
 Note: In a sidewall hybrid, add 1/4 wave length to B arm for equal phase at output.

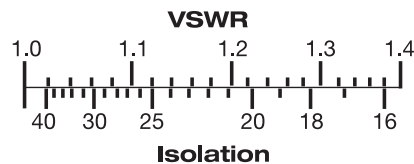
Theory

These couplers have a plane of symmetry running the full length of the unit, and are comprised of two waveguides side by side with a portion of the common wall removed to permit coupling between the two sections. Since these units are symmetrical, any of the four arms may be used as an input without impairing its performance.

In MDL short-slot 3 dB (hybrid) couplers the incoming power divides equally between the two output terminals. With the remaining arm isolated, this structure then becomes an ideal hybrid junction. If the output terminals (B&C) are short-circuited, the energy is reflected without relative phase shift. Voltages in the input arm (A) arising from reflections at short-circuit (C) experience an additional 90° phase shift, and thus cancel those which are reflected from short-circuit (B). The reflections arriving in arm (D) arising from the reflections at short-circuit (B) experience a 90° phase shift and thus reinforce those reflected from short-circuit (C).

Engineering Information

Most standard MDL 3 dB short slot (hybrid) couplers have a normal output power unbalance of 0.25 dB max., (a coupling of 3dB ± 0.125 dB) and an isolation exceeding 30 dB in applications up to and including 15% band width. The terminated VSWR is a function of isolation, and can be determined from the chart below. Generally, the VSWR is less than 1.07.



Each hybrid is designed for optimum isolation and flat balance response over as broad a band as possible. In a sidewall hybrid, the power out of the auxiliary arm lags the power out of the main arm, while in a topwall hybrid the power of the auxiliary arm leads the main arm (See Fig. 1). The parameters that cause phase error are:

1. Non-symmetry (seldom exceeds 2°)
2. A function of isolation, approximately equal to $2 \tan^{-1} \sqrt{I}^2$, where \sqrt{I} is isolation in voltage ratio. This can account for slightly over 0.1° error with 30 dB isolation.

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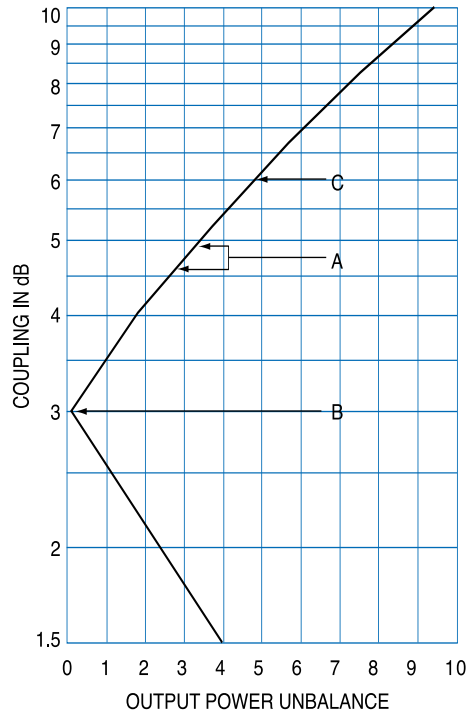
Terminology

The terms “Coupling,” “Balance,” “Directivity” and “Isolation” are occasionally misused. Coupling is the ratio of input power to the auxiliary guide output power while Balance is the ratio of the main guide output power to the auxiliary guide output power.

Directivity is the ratio of forward to reverse power in the auxiliary guide while isolation is the ratio of the main guide input power to reverse power in the auxiliary guide. Isolation is equal to coupling + directivity.

These and other common terms are illustrated and defined in Fig. 1. All Terms in Fig. 1 are expressed in decibels.

The graph illustrates the relationship between coupling and balance.

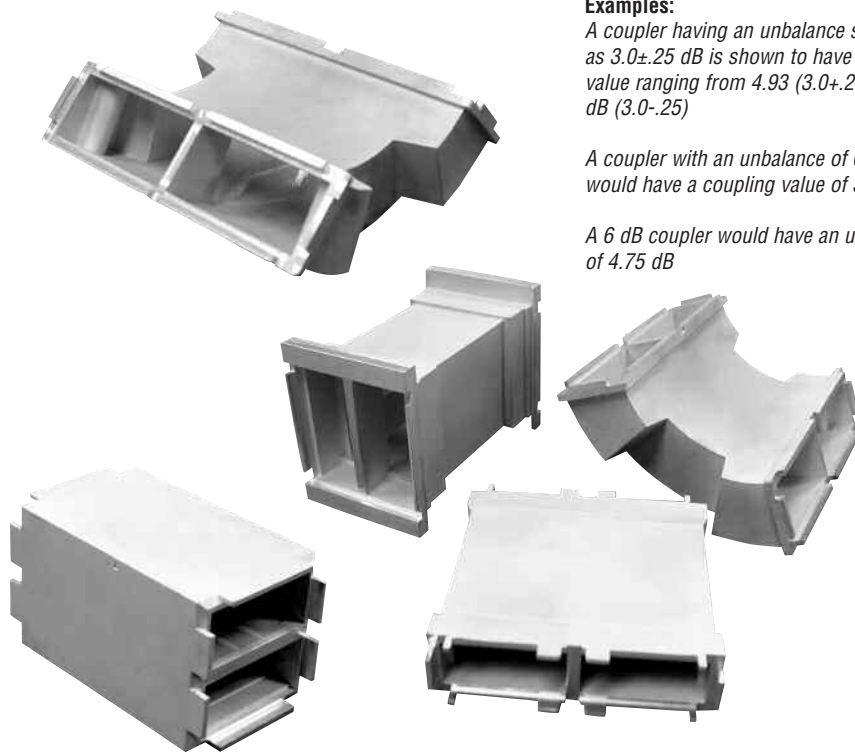


Examples:

A coupler having an unbalance specified as $3.0 \pm .25$ dB is shown to have a coupling value ranging from 4.93 ($3.0 + .25$) to 4.6 dB ($3.0 - .25$)

A coupler with an unbalance of 0.0 dB would have a coupling value of 3 dB

A 6 dB coupler would have an unbalance of 4.75 dB



Introduction

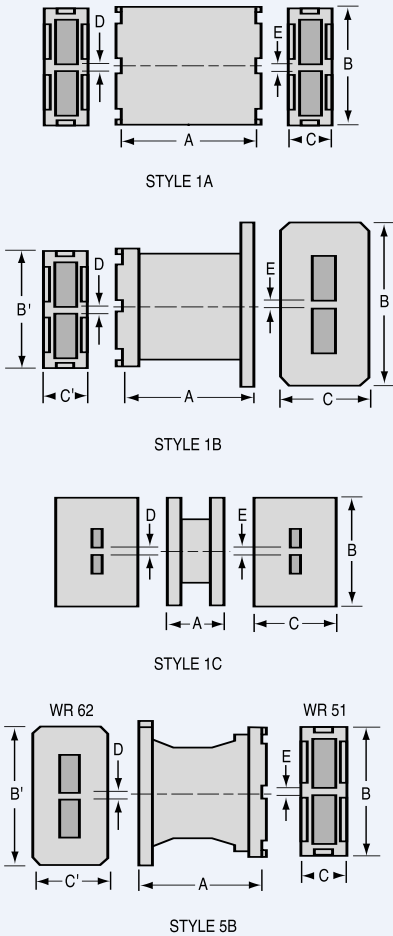
MDL has prepared this section as an up to date guide in the selection of short-slot couplers. This section is divided into four major groups: sidewall 3 dB couplers, topwall 3 dB couplers, sidewall couplers other than 3 dB and topwall couplers other than 3dB. These major groups are sub-divided into EIA waveguide size (WR10 thru 284).

MDL short-slot couplers, because of their uniplanar construction, simplify packaging, particularly where space is limited. Models are also available in 90° and 180° bends, narrow height waveguide and tapers from one guide to another.

The short-slot 3 dB (hybrid) couplers are ideal for compact power dividers, bridge circuits, duplexers, diplexers, monopulse comparators, balanced mixers, etc. MDL, the pioneer and largest manufacturer of short-slot couplers can produce a unit to meet your requirements. Quotations and inquiries are invited.

Sidewall Couplers – 3dB

SIDEWALL COUPLERS



| W/G Size | Frequency GHz | Style | Model Number | Dimensions (inches) | | | | |
|--------------------|--------------------------|-----------------|----------------------|---------------------|-----------------|----------------|------|------|
| | | | | A | B | C | D | E |
| WR10 | 91.75-95.75 ^X | 1C ² | 10HS12B ³ | .440 | 1.00 | .75 | .040 | .040 |
| WR22 | 43.5-45.5 | 1A | 22HS12 | .440 | .648 | .280 | .040 | .040 |
| WR28 | 26.5-29.5 | 1A | 28HS42 | .550 | .77 | .30 | .040 | .040 |
| | 26.0-30.0 [▲] | | | | | | | |
| | 27.5-31.2 | 1A | 28HSA22 | .550 | .77 | .30 | .040 | .040 |
| | 30.0-34.0 | 1A | 28HS52 | .550 | .76 | .30 | .040 | .040 |
| | 34.0-36.0 | 1A | 28HS32 | .550 | .77 | .30 | .040 | .040 |
| | 33.5-37.0 [▲] | | | | | | | |
| | 36.0-40.0 | 1A | 28HS62* | .550 | .77 | .30 | .040 | .040 |
| WR42 | 17.6-20.0 | 1A | 42HS42 | .900 | 1.11 | .31 | .090 | .090 |
| | 17.6-20.0 | 1B ¹ | 42HS14 | .900 | 1.39B 11.1B | .87C .32C | .090 | .090 |
| | 17.6-20.0 | 1C ¹ | 42HS24 | .900 | 1.39 | .87 | .090 | .090 |
| | 19.3-22.0 | 1A | 42HS32 | .900 | 1.11 | .29 | .090 | .090 |
| | 23.0-25.5 | 1A | 42HS12 | .900 | 1.09 | .33 | .040 | .090 |
| | 22.5-26.0 [▲] | | | | | | | |
| | 23.0-25.0 | 2A | 42HS22 | .500(R) | 1.07 | .31 | .040 | .090 |
| WR51 | 15.5-17.5 | 1A | 51HS62 | 1.375 | 1.33 | .47 | .090 | .090 |
| | 16.0-17.0 [■] | 1A | 51HS22 | 1.375 | 1.33 | .47 | .090 | .090 |
| | 17.35-19.65 | 1A | 51HS12 | 1.125 | 1.22 | .42 | .040 | .040 |
| | 17.35-19.65 | 1A | 51HS32 | 1.125 | 1.27 | .42 | .090 | .090 |
| WR51 Tapered to | 15.5-16.5 | 5B ⁵ | 51HS42 | 1.250 | 1.27B 1.75B' | .42C 1.31C' | .040 | .090 |
| WR62 | 15.5-16.5 | 5B ⁷ | 51HS52 | 1.250 | 1.27B 1.75B' | .42C 1.31C' | .040 | .090 |
| WR62 | 12.4-14.0 | 1A | 62HS22 | 1.110 | 1.45 | .48 | .040 | .040 |
| | 12.4-14.0 | 1A | 62HS132 | 1.110 | 1.50 | .48 | .090 | .090 |

Except as Noted Output power Unbalance (dBmax.) ± 0.25 Isolation (db min.) 30

Notes: ^X Unbalance $\pm .50$ dB max. Isolation 25 dB min. ^{*} Isolation 28 dB min.

[■] Unbalance $\pm .15$ dB max.

[▲] These models have been tested and exhibit reasonable electrical characteristics over extended frequency range. Specific data available on request.

¹ Dual flat flange with four .116 dia. cleared holes 42FS32

² Dual flat flange with six .120 dia. cleared holes 10FS22

³ Material BECU only

⁵ Dual sidewall flat flange four 0.144 dia. holes 62FS52

⁷ Dual choke pressure flange 62FS12 four 0.144 dia. holes

NOTE: All hybrids corrals mate with standard W/G (WR size noted in the table on Page 51) having a common wall of the thickness shown by dimensions D and E.

Socket dimensions & overall tolerances shown on Page 44.

Sidewall Couplers – 3dB

| W/G Size | Frequency GHz | Style | Model Number | Dimensions (inches) | | | | | |
|---------------|------------------------|--------------------|--------------|---------------------|-----------------|----------------|------|------|------|
| | | | | A | B | C | D | E | |
| WR62 (cont.) | 12.4-14.0 | 1B ⁶ | 62HS54 | 1.250 | 1.75B 1.46B' | 1.31C .48C' | .040 | .040 | |
| | 13.0-15.0* | 1A | 62HS162 | 1.250 | 1.50 | .48 | .090 | .090 | |
| | 13.5-15.6 | 1A | 62HS122 | 1.250 | 1.50 | .48 | .090 | .090 | |
| | 13.5-15.6 | 1A | 62HS12 | 1.250 | 1.45 | .48 | .040 | .040 | |
| | 13.5-15.8 | 1B ⁶ | 62HS64 | 1.250 | 1.75B 1.46B' | 1.31C .48C' | .040 | .040 | |
| | 15.0-17.0 | 1A | 62HS32 | 1.110 | 1.45 | .48 | .040 | .040 | |
| | 15.0-17.0 | 1A | 62HS152 | 1.110 | 1.50 | .48 | .090 | .090 | |
| | 15.5-17.5 | 1A | 62HS112 | 1.110 | 1.53 | .51 | .090 | .090 | |
| | 15.5-17.5 | 1B ⁸ | 62HS142 | 1.110 | 1.80B 1.50B' | 1.31C .48C' | .090 | .090 | |
| | 15.5-17.5 | 1B ⁹ | 62HS84 | 1.110 | 1.80B 1.50B' | 1.31C .48C' | .090 | .090 | |
| | 15.5-17.5 | 1A | 62HSA52 | 1.312 | 1.53 | .50 | .090 | .040 | |
| | 15.5-17.5 | 1B ^{7,11} | 62HSA14 | 1.360 ¹⁰ | 1.75B 1.53B' | 1.31C .50C' | .090 | .040 | |
| | 15.5-17.5 | 1B ⁵ | 62HSA44 | 1.360 | 1.75B 1.53B' | 1.31C .50C' | .090 | .040 | |
| | 15.5-17.5 | 1A | 62HSA42 | 1.110 | 1.45 | .47 | .040 | .040 | |
| | 15.5-18.0 [▲] | | | | | | | | |
| | WR62 90° | 15.5-17.0 | 2A | 62HSA92 | .750 (R) | 1.61 | .58 | .040 | .090 |
| | WR62.138 HGT | 12.6-14.2 | 1A | B62HS12 | 1.110 | 1.43 | .28 | .040 | .040 |
| 12.6-14.2 | | 1D | B62HS22 | 1.110 | 1.36 | .22 | .040 | .040 | |
| WR75 | 10.1-11.6 | 1A | 75HS32 | 1.375 | 1.75 | .58 | .050 | .050 | |
| | 10.5-12.0 | 1A | 75HS12 | 1.375 | 1.75 | .58 | .050 | .050 | |
| | 11.6-13.4 | 1A | 75HS22 | 1.500 | 1.75 | .58 | .050 | .050 | |
| | 11.7-14.3*+ | 1A | 75HS42 | 1.500 | 1.75 | .58 | .050 | .050 | |
| | 13.0-15.0 | 1A | 75HS52 | 1.375 | 1.75 | .58 | .050 | .050 | |
| WR75 .200 HGT | 10.0-10.5 | 1A | A75HS12 | 1.375 | 1.75 | .40 | .050 | .050 | |
| WR90 | 8.10-9.30 | 1A | 90HS342 | 1.735 | 2.13 | .61 | .120 | .120 | |
| | 8.10-9.30 | 1B ³ | 90HS94 | 1.735 | 2.58B 2.13B' | 1.62C .61C' | .120 | .120 | |

Except as Noted Output power Unbalance (dBmax.) ±0.25 Isolation (db min.) 30

Notes: * Isolation 28 dB min. + Unbalance ±.50 dB.

⁵ Dual sidewall flat flange four 0.144 dia. holes 62FS52

⁶ Dual S/W blank flange (no holes)

⁷ Dual choke pressure flange 62FS12 four 0.144 dia. holes

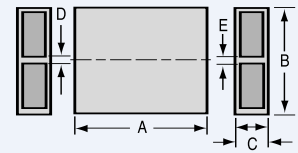
⁸ Dual S/W flat flange four 0.144 dia. holes 62FS92

⁹ Dual S/W pressure flange six 0.144 dia. holes

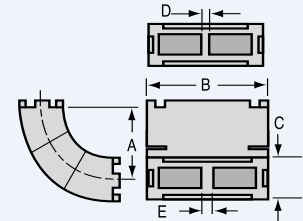
NOTE: All hybrids corrals mate with standard W/G (WR size noted in the table on Page 51) having a common wall of the thickness shown by dimensions D and E.

Socket dimensions & overall tolerances shown on Page 44.

SIDEWALL COUPLERS



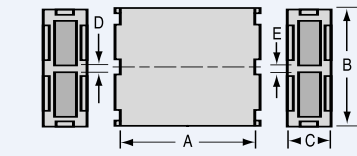
STYLE 1D



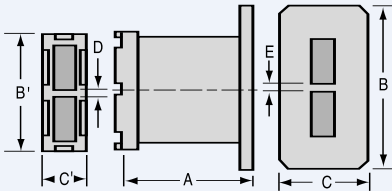
STYLE 2A

Sidewall Couplers – 3dB

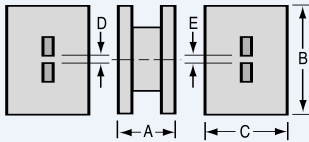
SIDEWALL COUPLERS



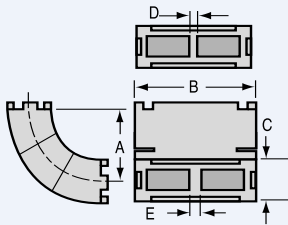
STYLE 1A



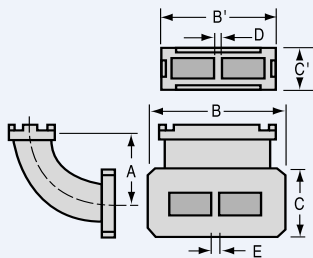
STYLE 1B



STYLE 1C



STYLE 2A



STYLE 2B

| W/G Size | Frequency GHz | Style | Model Number | Dimensions (inches) | | | | |
|---------------------------|-----------------|------------------|--------------|---------------------|-----------------|----------------|------|------|
| | | | | A | B | C | D | E |
| WR90 (cont.) | 8.5-9.7 | 1B ³ | 90HS84 | 1.735 | 2.58B 2.13B' | 1.62C .61C' | .120 | .120 |
| | 8.5-9.6 | 1A ¹ | 90HS52 | 1.235 | 2.00 | .56 | .050 | .050 |
| | 8.4-9.6 | 1A | 90HS272 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 8.5-9.7 | 1A | 90HSA232 | 1.735 | 2.13 | .61 | .120 | .120 |
| | 8.5-9.6 | 1A | 90HS322 | 1.735 | 2.12B 2.05B' | .60 | .050 | .120 |
| | 8.5-9.7 | 1B ^{4B} | 90HS54 | 1.875 | 2.58B 2.14B' | 1.63C .61C' | .120 | .050 |
| | 8.5-9.7 | 1B ^{4A} | 90HS24 | 1.875 | 2.58B 2.14B' | 1.63C .61C' | .120 | .050 |
| | 8.6-10.0 | 1A | 90HS92 | 2.000 | 2.14 | .61 | .120 | .120 |
| | 8.8-10.0 | 1A | 90HSA242 | 1.485 | 2.06 | .60 | .050 | .050 |
| | 9.10-10.20 | 1A | 90HS152 | 1.735 | 2.13 | .61 | .120 | .120 |
| | 9.10-10.20 | 1B ³ | 90HS74 | 1.735 | 2.58B 2.13B' | 1.62C .61C' | .120 | .120 |
| | 9.0-10.0 | 1A | 90HS112 | 1.875 | 2.14 | .61 | .050 | .120 |
| | 9.0-10.0 | 1B ^{4A} | 90HS144 | 1.875 | 2.58B 2.14B' | 1.63C .61C' | .120 | .050 |
| | 9.4-10.8 | 1A | 90HS82 | 2.000 | 2.13 | .61 | .120 | .120 |
| | 9.6-10.25 | 1A | 90HSA252 | 1.485 | 2.03 | .59 | .050 | .050 |
| 10.5-11.9 | 1A | 90HS42 | 1.735 | 2.13 | .61 | .120 | .120 | |
| 10.5-11.9 | 1C ² | 90HS44 | 1.735 | 2.80 | 1.27 | .120 | .120 | |
| WR90 60° | 8.4-9.7 | 4B ² | 90HS114 | 1.680(R) | 2.84B 2.03B' | 1.38C .58C' | .050 | .050 |
| | 8.5-9.6 | 2A | 90HS12 | 1.125(R) | 2.04 | .60 | .050 | .050 |
| WR90 90° | 8.5-9.6 | 2A | 90HS292 | 1.125(R) | 2.12 | .61 | .120 | .120 |
| | 8.8-10.0 | 2A | 90HS332 | 1.125(R) | 2.10 | .60 | .050 | .050 |
| | 9.6-10.7 | 2A | 90HS22 | 1.125(R) | 2.13 | .61 | .120 | .120 |
| | 9.6-10.7 | 2B ³ | 90HS64 | 1.125(R) | 2.54B 2.12B' | 1.62C .61C' | .120 | .120 |
| | 8.5-9.6 | 3A | 90HS102 | 1.100(D) | 2.15 | .70 | .050 | .050 |
| WR90 180° | 8.4-9.6 | 3A | 90HS142 | 1.095(D) | 2.22 | .70 | .120 | .120 |
| | 8.5-9.6 | 5A | 90HS62 | 2.187 | 2.11B 2.62B' | .60C .72C' | .120 | .120 |
| WR90 Tapered to WR112 | 8.5-9.6 | 6A | 90HS132 | 1.312(R) | 2.13B 2.60B' | .62C .71C' | .120 | .150 |
| WR90 Tapered to WR112 90° | 8.2-9.3 | 1A | A90HS12 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90HS22 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 9.4-10.8 | 1A | A90HS32 | 1.735 | 2.12 | .40 | .120 | .120 |
| WR90 .200 HGT | 8.5-9.6 | 1A | B90HS22 | 1.735 | 2.14B 2.14B' | .63C .53C' | .120 | .120 |
| | 8.5-9.6 | 1A | B90HS22 | 1.735 | 2.14B 2.14B' | .63C .53C' | .120 | .120 |

Except as Noted Output power Unbalance (dBmax.) ±.25 Isolation (db min.) 30

Notes: • Isolation 27 dB min.

¹ No physical center wall .050 commonwall required by both mating components to function electrically

² Flange blank

³ Dual S/W flat flanges six .169 dia. holes 90FS112

^{4A} Dual S/W pressure flange 90FS152 six .169 dia.

^{4B} Dual S/W pressure flange 90FS162 six 8/32 threaded

NOTE: All hybrids corrals mate with standard W/G (WR size noted in the table on Page 51) having a common wall of the thickness shown by dimensions D and E.

Socket dimensions & overall tolerances shown on Page 44.

Sidewall Couplers – 3dB

| W/G Size | Frequency GHz | Style | Model Number | Dimensions (inches) | | | | |
|------------------------------------|--------------------------|-----------------|--------------|---------------------|-----------------|-----------------|------|------|
| | | | | A | B | C | D | E |
| WR90 Tapered to .300 HGT 90° | 8.5-9.6 | 6A | B90HS12 | 1.125(R) | 2.10B 2.10B' | .50C .60C' | .120 | .120 |
| | 9.5-10.5 | 6A | B90HS42 | 1.124(R) | 2.10B 2.10B' | .50C .60C' | .120 | .120 |
| WR90 .150 HGT | 8.5-9.6 | 1A | C90HS12 | 1.580 | 2.07 | .35 | .070 | .070 |
| WR102 | 9.4-10.6 | 1A | 102HS12 | 2.250 | 2.450 | .77 | .150 | .150 |
| | 9.4-10.6 | 1B | 102HS22 | 2.250 | 3.48B 2.45B' | 1.78C .77C' | .150 | .150 |
| WR112 | 6.9-8.0 | 1A | 112HS12 | 2.187 | 2.64 | .73 | .150 | .150 |
| | 7.1-8.5** | 1A | 112HS32 | 2.187 | 2.64 | .73 | .150 | .150 |
| | 7.1-8.5** | 1B ⁷ | 112HS44 | 2.187 | 3.218 2.64 | 1.375 .73 | .150 | .150 |
| | 7.5-8.5 | 1A | 112HS62 | 2.187 | 2.64 | .73 | .150 | .150 |
| | 7.9-9.0 | 1A | 112HS142 | 2.187 | 2.64 | .74 | .150 | .150 |
| | 8.4-9.6 | 1B | 112HS34 | 2.000 | 3.21B 2.52B' | 1.37C .72C' | .064 | .064 |
| | 8.4-9.8 | 1A | 112HS72 | 2.000 | 2.53 | .73 | .064 | .064 |
| | 8.5-9.7 | 1A | 112HS112 | 2.187 | 2.61B 2.53B' | .72 | .064 | .150 |
| | 8.5-9.6 | 1B ⁵ | 112HS14 | 2.437 | 3.06B 2.53B' | 1.87C .73C' | .064 | .064 |
| | 8.5-9.7 | 1B ⁶ | 112HS24 | 2.187 | 3.22B 2.61B' | 1.38C .72C' | .150 | .064 |
| WR112 90° | 8.5-9.6 | 2A | 112HS122 | 1.312(R) | 2.64 | .83 | .064 | .064 |
| | 8.5-9.6 | 2A | 112HS102 | 1.312(R) | 2.66 | .77 | .064 | .150 |
| WR112 180° | 8.5-9.6 | 3A | 112HS22 | 1.375(D) | 2.62 | .72 | .150 | .150 |
| WR137 | 5.4-6.0 | 1A [*] | 137HS12 | 2.750 | 3.15 | .88 | .150 | .150 |
| | 5.4-6.0 | 1B ¹ | 137HS14 | 2.750 | 3.80B 3.14B' | 1.61C .88C' | .150 | .150 |
| | 5.8-6.5 | 1A | 137HS72 | 2.625 | 3.11 | .83 | .150 | .150 |
| | 6.0-7.0 | 1A | 137HS52 | 2.625 | 3.09 | .83 | .150 | .150 |
| | 6.85-7.80 | 1A | 137HS32 | 2.625 | 3.13 | .88 | .150 | .150 |
| WR137 .247 HGT | 7.15-8.20 | 1A | 137HS22 | 2.625 | 3.13 | .88 | .150 | .150 |
| | 5.4-6.0 | 1A | A137HS12 | 2.625 | 3.13 | .48 | .150 | .150 |
| WR137 .487 HGT | 6.0-7.0 | 1B ² | B137HS14 | 2.625 | 3.80B 3.09B' | 1.40C 0.69C' | .150 | .150 |
| WR159 | 5.4-5.9 | 1A | 159HS22 | 3.250 | 3.56 | 1.02 | .150 | .150 |
| | 5.9-6.5 | 1A | 159HS12 | 3.250 | 3.56 | 1.02 | .150 | .150 |
| | 5.925-6.425 [■] | 1A | 159HSA12 | 3.250 | 3.56 | 1.02 | .150 | .150 |
| | 5.9-6.5 | 1B ³ | 159HS14 | 3.250 | 4.20B 3.56B' | 1.67C 1.02C' | .150 | .150 |
| | 5.9-6.5 | 1C ³ | 159HS24 | 3.250 | 4.20 | 1.67 | .150 | .150 |

Except as Noted Output power Unbalance (dBmax.) ±.25 Isolation (db min.) 30

Notes: * Coralls same as Style 1B ** Isolation 28 unbalance, .35 dB min.

■ Unbalance ±.15 dB max. Isolation 35 dB min.

¹ Dual S/W flat flange 137FS32

² Dual S/W flat flange B 137FS12

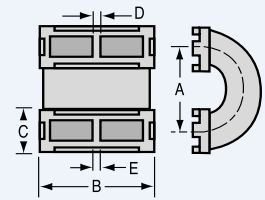
⁵ Dual S/W pressurized choke flange six 0.169 dia. holes 112FS22

⁶ Dual S/W pressure flat flange ten 0.167 dia. holes 112FS102

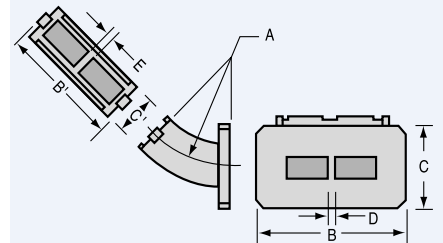
⁷ Dual S/W flat flange ten 0.169 dia. holes 112FS82

NOTE: All hybrids coralls mate with standard W/G (WR size noted in the table on Page 51) having a common wall of the thickness shown by dimensions D and E. Socket dimensions & overall tolerances shown on Page 44.

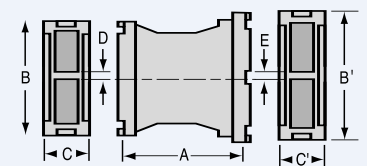
SIDEWALL COUPLERS



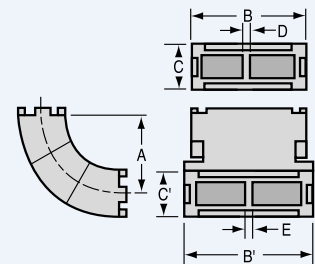
STYLE 3A



STYLE 4B

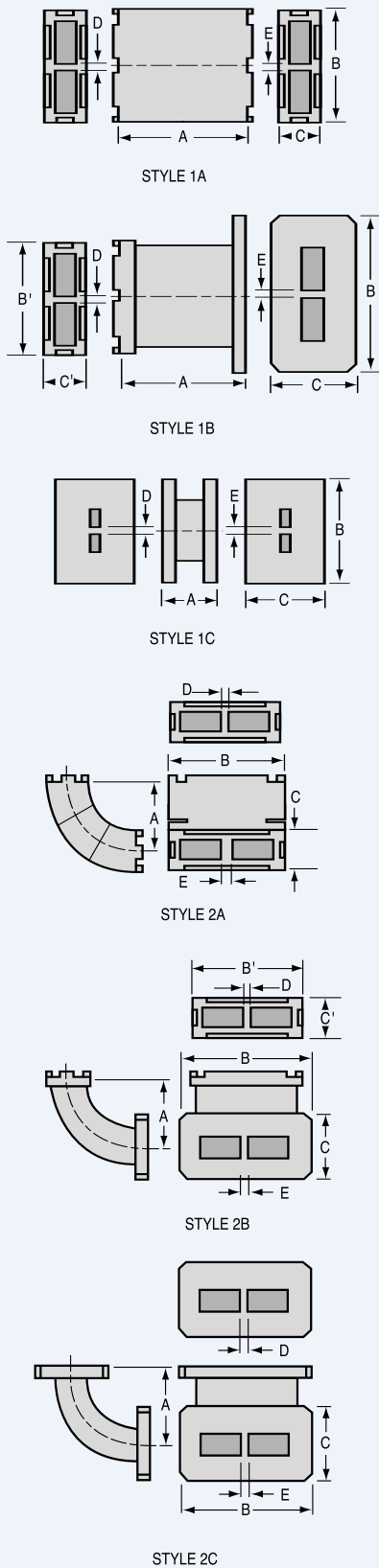


STYLE 5A



STYLE 6A

Sidewall Couplers – 3dB



| W/G Size | Frequency GHz | Style | Model Number | Dimensions (inches) | | | | |
|--------------|---------------|------------------|--------------|---------------------|-----------------|-----------------|------|------|
| | | | | A | B | C | D | E |
| WR187 | 3.95-4.50 | 1A | 187HSA92 | 3.625 | 4.17 | 1.17 | .150 | .150 |
| | 3.95-4.50 | 1B ⁴ | 187HSA84 | 3.625 | 4.76B 4.17B' | 1.77C 1.17C' | .150 | .150 |
| | 3.95-4.50 | 1C ⁴ | 187HS74 | 3.625 | 4.76 | 1.77 | .150 | .150 |
| | 4.34-5.06 | 1A | 187HSA32 | 3.625 | 4.17 | 1.17 | .150 | .150 |
| | 4.34-5.06 | 1C ⁴ | 187HS44 | 3.625 | 4.76 | 1.77 | .150 | .150 |
| | 4.34-5.06 | 1B ⁴ | 187HS94 | 3.625 | 4.76B 4.17B' | 1.77C 1.17C' | .150 | .150 |
| | 4.50-5.20 | 1A | 187HSA52 | 3.625 | 4.17 | 1.17 | .150 | .150 |
| | 4.50-5.20 | 1B ⁴ | 187HSA64 | 3.625 | 4.76B 4.17B' | 1.77C 1.17C' | .150 | .150 |
| | 4.50-5.20 | 1C ⁴ | 187HS54 | 3.625 | 4.76 | 1.77 | .150 | .150 |
| | 4.70-5.25 | 1A | 187HS62 | 3.625 | 4.14 | 1.13 | .128 | .128 |
| | 4.90-5.75 | 1A | 187HS72 | 3.625 | 4.14 | 1.13 | .150 | .150 |
| | 5.2-5.9 | 1A | 187HSA42 | 3.250 | 4.14 | 1.14 | .128 | .128 |
| | 5.2-5.9 | 1B ^{5A} | 187HSA24 | 3.250 | 5.02B 4.14B' | 2.01C 1.14C' | .128 | .128 |
| | 5.2-5.9 | 1B ^{5B} | 187HSA14 | 3.250 | 5.02B 4.14B' | 2.01C 1.14C' | .128 | .128 |
| WR187 90° | 3.8-4.3 | 2C ³ | 187HS13 | 2.250(R) | 4.75 | 1.78 | .150 | .150 |
| | 3.8-4.3 | 2A | 187HS112 | 2.250(R) | 4.15 | 1.13 | .150 | .150 |
| | 4.4-5.0 | 2A | 187HS22 | 2.375(R) | 4.14 | 1.12 | .150 | .150 |
| | 5.2-5.9 | 2A | 187HS82 | 2.250(R) | 4.19 | 1.20 | .128 | .128 |
| | 5.2-5.9 | 2B ^{5A} | 187HS34 | 2.250(R) | 5.02B 4.19B' | 2.01C 1.20C' | .128 | .128 |
| | 3.7-4.2 | 1A | 229HS12 | 5.25 | 4.96 | 1.40 | .128 | .128 |
| WR284 | 2.66-2.99 | 1A | 284HS32 | 5.50 | 6.14 | 1.62 | .160 | .160 |
| | 2.7-2.9 | 1A | 284HS22 | 5.50 | 6.14 | 1.62 | .160 | .160 |
| | 2.7-2.9 | 1C ⁶ | 284HS14 | 5.50 | 7.22 | 2.72 | .160 | .160 |
| | 2.7-2.9 | 1A | 284HS92 | 5.50 | 6.18 | 1.67 | .160 | .160 |
| | 2.8-3.2 | 1A | 284HS12 | 5.50 | 6.14 | 1.62 | .160 | .160 |
| | 2.99-3.44 | 1A | 284HS52 | 5.50 | 6.14 | 1.62 | .160 | .160 |
| | 3.1-3.5 | 1A | 284HS102 | 5.50 | 6.18 | 1.67 | .160 | .160 |
| | 3.44-3.95 | 1A | 284HS42 | 5.50 | 6.11 | 1.62 | .160 | .160 |
| | 3.1-3.5 | 1A ⁸ | A284HS22 | 5.50 | 6.16 | .72 | .160 | .160 |
| | 3.1-3.5 | 1A ⁷ | A284HS32 | 5.50 | 6.16 | .99 | .160 | .160 |
| WR284 90° | 2.85-3.15 | 1A | 284HS62 | 3.50(R) | 6.20 | 1.60 | .160 | .160 |

Except as Noted Output power Unbalance (dBmax.) ±.25 Isolation (db min.) 30

Notes: ³ Blank flange

⁴ Dual s/w flat flange 187FS92

^{5A} Dual sidewall flat pressure flange twelve 0.196 dia. holes (187FS52)

^{5B} Dual sidewall flat pressure flange twelve 10.32 threaded holes (187FS62)

⁶ Dual S/W flat flange 284FS12

⁷ .670 height

⁸ .400 height

NOTE: All hybrids corrals mate with standard W/G (WR size noted in the table on Page 51) having a common wall of the thickness shown by dimensions D and E.

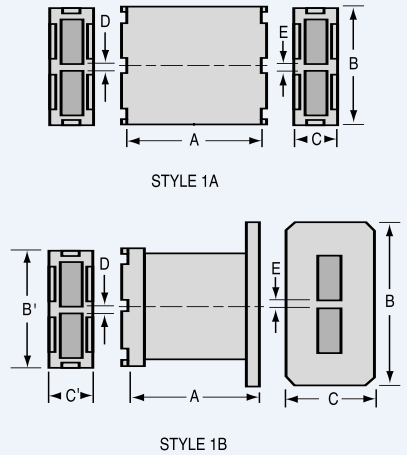
Socket dimensions & overall tolerances shown on Page 44.

Sidewall Couplers – Other than 3dB

SIDEWALL COUPLERS – OTHER THAN 3dB

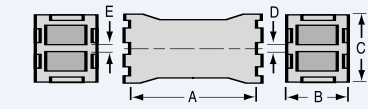
| W/G Size | Electrical Data | | | | | | Mechanical Data (inches) | | | | |
|-------------------------|-----------------|-----------------|--------------|-------------------------|-----------------------------|----------------------|--------------------------|-----------------|----------------|------|------|
| | Frequency GHz | Style | Model Number | Coupling Reference (dB) | Output Power Unbalance (dB) | Directivity (dB min) | A | B | C | D | E |
| WR28 | 38.0-40.2 | 1A | 28CH12 | 4.8 | -3.0 ±.25 | 20 | .550 | .77 | .30 | .040 | .040 |
| WR42 | 19.5-22.5 | 1A | 42CH12 | 4.8 | -3.0 ±.25 | 18 | .900 | 1.11 | .29 | .090 | .090 |
| WR62 | 12.0-14.0 | 1A | 62CH12 | 4.8 | -3.0 ±.25 | 15 | 1.110 | 1.44 | .47 | .040 | .040 |
| | 12.6-14.0 | 1A | 62CH102 | 4.8 | -3.0 ±.25 | 20 | 1.110 | 1.44 | .47 | .040 | .040 |
| | 12.6-14.4 | 1A | 62CH32 | 5.6 | -4.2 ±.25 | 20 | 1.110 | 1.45 | .46 | .040 | .040 |
| | 12.6-14.6 | 1A | 62CH42 | 5.4 | -3.95 ±.25 | 20 | 1.110 | 1.45 | .46 | .040 | .040 |
| | 13.0-14.5 | 1A | 62CH52 | 6.0 | -4.8 ±.25 | 20 | 1.110 | 1.45 | .46 | .040 | .040 |
| | 13.1-14.3 | 1A | 62CH72 | 6.2 | -5.0 ±.25 | 20 | 1.110 | 1.45 | .46 | .040 | .040 |
| | 13.5-15.5 | 1A | 62CH62 | 4.8 | -3.0 ±.25 | 18 | 1.250 | 1.50 | .48 | .090 | .090 |
| | 15.0-17.0 | 1A | 62CH22 | 4.8 | -3.0 ±.25 | 20 | 1.110 | 1.44 | .47 | .040 | .040 |
| | 15.4-17.4 | 1B ¹ | 62CH92 | 4.8 | -3.0 ±.25 | 22 | 1.110 | 1.75B 1.45B' | 1.30C .48C' | .040 | .040 |
| WR75 | 10.7-11.7 | 1A | 75CH12 | 6.0 | -4.8 ±.25 | 24 | 1.375 | 1.75 | .58 | .050 | .050 |
| WR90 | 8.2-9.2 | 1A | 90CH52 | 7.0 | -6.1 ±.25 | 20 | 1.735 | 2.14 | .69 | .120 | .120 |
| | 8.5-9.6 | 1A | 90CH12 | 4.8 | -3.0 ±.25 | 22 | 1.735 | 2.13 | .63 | .120 | .120 |
| | 8.5-9.6 | 1A | 90CH62 | 3.5 | -1.0 ±.25 | 25 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 8.7-9.6 | 1A | 90CH72 | 5.8 | -4.5 ±.25 | 15 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 8.8-9.6 | 1A | 90CH82 | 2.5 | +1.0 ±.25 | 25 | 1.735 | 2.06 | .66 | .050 | .050 |
| | 8.8-9.8 | 1A | 90CH92 | 5.5 | -4.0 ±.25 | 15 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 9.1-9.6 | 1A | 90CH102 | 6.0 | -4.9 ±.25 | 22 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 9.1-9.65 | 1A | 90CH112 | 4.0 | -1.8 ±.25 | 20 | 1.735 | 2.06 | .59 | .050 | .050 |
| | 9.3-11.0 | 1A | 90CH122 | 5.2 | -3.7 ±.25 | 15 | 2.000 | 2.13 | .61 | .120 | .120 |
| | 9.5-10.3 | 1A | 90CH132 | 5.2 | -3.7 ±.25 | 20 | 2.000 | 2.13 | .61 | .120 | .120 |
| 9.5-11.0 | 1A | 90CH32 | 4.8 | -3.0 ±.25 | 20 | 2.000 | 2.13 | .61 | .120 | .120 | |
| 9.7-10.0 | 1A | 90CH142 | 5.5 | -4.0 ±.25 | 18 | 1.735 | 2.06 | .59 | .050 | .050 | |
| WR90 200 HGT | 8.5-9.6 | 1A | A90CH12 | -3.2 | -4.0 ±.40 | 25 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90CH22 | -3.5 | -1.00 ±.25 | 25 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90CH32 | -3.75 | -1.40 ±.25 | 23 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90CH42 | -4.0 | -1.80 ±.25 | 20 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90CH52 | -4.8 | -3.00 ±.25 | 20 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 8.5-9.6 | 1A | A90CH62 | -5.4 | -3.90 ±.25 | 15 | 1.735 | 2.12 | .40 | .120 | .120 |
| | 9.3-10.3 | 1A | A90CH72 | -5.2 | -3.64 ±.25 | 24 | 1.735 | 2.12 | .42 | .120 | .120 |
| | 9.3-10.3 | 1A | A90CH82 | 6.96 | -5.98 ±.25 | 20 | 1.735 | 2.12 | .47 | .120 | .120 |
| 9.3-10.3 | 1A | A90CH92 | 7.65 | -6.83 ±.25 | 14 | 1.735 | 2.12 | .49 | .120 | .120 | |
| WR112 | 7.25-7.75 | 1A | 112CH32 | 4.8 | -3.0 ±.25 | 20 | 2.187 | 2.64 | .73 | .150 | .150 |
| | 7.25-8.75 | 1A | 112CH12 | 4.8 | -3.0 ±.25 | 20 | 2.187 | 2.64 | .73 | .150 | .150 |
| | 8.5-9.6 | 1A | 112CH22 | 4.8 | -3.0 ±.25 | 20 | 2.000 | 2.53 | .73 | .064 | .064 |
| WR137 | 5.3-6.3 | 1A | 137CH12 | 4.8 | -3.0 ±.30 | 20 | 2.750 | 3.15 | .88 | .150 | .150 |
| | 5.5-6.2 | 1A | 137CH22 | 5.0 | -3.3 ±.30 | 22 | 2.750 | 3.15 | .88 | .150 | .150 |

Notes: ¹ Similar to 430FA12 flanges

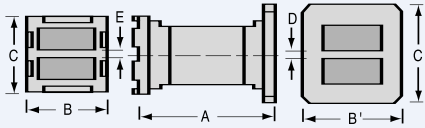


Topwall Couplers – 3dB

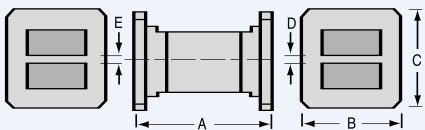
TOPWALL COUPLERS – 3dB



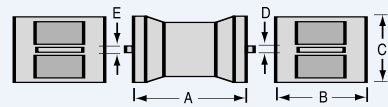
STYLE 7A



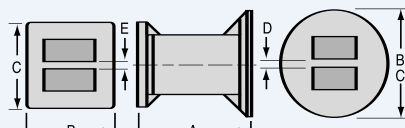
STYLE 7B



STYLE 7C



STYLE 7E



STYLE 7F

| W/G Size | Electrical Data | | | | | Mechanical Data (inches) | | | | |
|----------|-----------------|-----------------|--------------|-----------------------------|--------------------|--------------------------|-----------------|-----------------|------|------|
| | Frequency GHz | Style | Model Number | Output Power Unbalance (dB) | Isolation (dB min) | A | B | C | D | E |
| WR51 | 15.0-17.5 | 7A | 51HT22 | ±.25 | 30 | .975 | .66 | .70 | .040 | .040 |
| | 17.1-20.0 | 7A | 51HT12 | ±.25 | 30 | 1.125 | .67 | .72 | .040 | .040 |
| WR62 | 13.3-15.6 | 7A | 62HT82 | ±.25 | 30 | 1.250 | .78 | .88 | .090 | .090 |
| | 15.0-17.0 | 7A | 62HT22 | ±.25 | 30 | 1.110 | .78 | .88 | .090 | .090 |
| | 15.0-17.5 | 7A | 62HT72 | ±.25 | 30 | 1.110 | .78 | .88 | .090 | .090 |
| | 15.5-17.5 | 7A | 62HT52 | ±.25 | 30 | 1.110 | .78 | .88 | .090 | .090 |
| | 16.0-17.0 | 7A | 62HT32 | ±.25 | 35 | 1.110 | .78 | .88 | .090 | .090 |
| WR90 | 8.5-9.6 | 7A | 90HT22 | ±.25 | 30 | 1.735 | 1.13 | 1.14 | .120 | .120 |
| | 9.0-9.2 | 7A | 90HT112 | ±.40 | 25 | 1.735 | 1.14 | 1.16 | .120 | .120 |
| | 9.2-11.0 | 7A | 90HT112 | ±.40 | 28 | 1.735 | 1.14 | 1.16 | .120 | .120 |
| | 9.4-10.8 | 7A | 90HT92 | ±.25 | 30 | 1.735 | 1.14 | 1.16 | .120 | .120 |
| WR112 | 7.5-7.7 | 7A | 112HT12 | ±.45 | 25 | 2.000 | 1.34 | 1.38 | .150 | .150 |
| | 7.7-9.6 | 7A | 112HT12 | ±.45 | 28 | 2.000 | 1.34 | 1.38 | .150 | .150 |
| | 7.9-9.3 | 7A | 112HT22 | ±.25 | 30 | 2.000 | 1.34 | 1.38 | .150 | .150 |
| WR137 | 5.2-6.0 | 7A | 137HT82 | ±.25 | 30 | 2.625 | 1.63 | 1.64 | .150 | .150 |
| | 5.2-6.7 | 7E | 137HT42 | ±.60 | 28 | 2.750 | 2.13 | 1.53 | .150 | .150 |
| | 5.4-5.9 | 7A | 137HT72 | ±.15 | 35 | 2.625 | 1.63 | 1.64 | .150 | .150 |
| | 6.7-8.2 | 7E | 137HT52 | ±.45 | 26 | 2.750 | 2.13 | 1.53 | .150 | .150 |
| WR187 | 4.0-5.2 | 7E | 187HT32 | ±.60 | 28 | 3.750 | 2.59 | 2.09 | .150 | .150 |
| | 4.3-5.0 | 7A | 187HT62 | ±.25 | 30 | 3.535 | 2.61 | 2.12 | .150 | .150 |
| | 5.0-5.6 | 7A | 187HT22 | ±.25 | 30 | 3.625 | 2.14 | 2.16 | .150 | .150 |
| | 5.1-5.9 | 7A | 187HT42 | ±.25 | 30 | 3.625 | 2.13 | 2.14 | .150 | .150 |
| | 5.1-5.9 | 7A | 187HT42 | ±.25 | 30 | 3.625 | 2.13 | 2.14 | .150 | .150 |
| WR229 | 3.7-4.2 | 7A | 229HT12 | ±.25 | 30 | 4.250 | 2.57 | 2.69 | .128 | .128 |
| WR284 | 2.5-3.0 | 7F | 284HT64 | ±.25 | 30 | 4.660 | 4.09B 5.00B' | 4.09C 5.00C' | .160 | .160 |
| | 2.7-2.9 | 7A | 284HT12 | ±.25 | 30 | 4.750 | 3.19 | 3.19 | .160 | .160 |
| | 2.7-2.9 | 7B ¹ | 284HT34 | ±.25 | 30 | 4.750 | 3.19B 4.70B' | 3.19C 4.70C' | .160 | .160 |
| | 2.7-2.9 | 7C ¹ | 284HT44 | ±.25 | 30 | 4.750 | 4.70 | 4.70 | .160 | .160 |
| | 2.75-3.25 | 7A | 284HT22 | ±.25 | 30 | 4.750 | 3.19 | 3.19 | .160 | .160 |
| | 2.7-3.3 | 7A | 284HT22 | ±.35 | 28 | 4.750 | 3.19 | 3.19 | .160 | .160 |
| | 2.7-3.25 | 7B ¹ | 284HT14 | ±.25 | 30 | 4.750 | 3.19B | 3.19C | .160 | .160 |
| | 2.7-3.3 | 7B ¹ | 284HT14 | ±.35 | 28 | 4.750 | 4.70B' | 4.70C' | .160 | .160 |
| | 2.75-3.25 | 7C ¹ | 284HT24 | ±.25 | 30 | 4.750 | 4.70 | 4.70 | .160 | .160 |
| | 2.7-3.3 | 7C ¹ | 284HT24 | ±.35 | 28 | 4.750 | 4.70 | 4.70 | .160 | .160 |
| | 2.7-3.7 | 7B ¹ | 284HT54 | ±1.0 | 20 | 5.500 | 3.19B 4.70B' | 3.19C 4.70C' | .160 | .160 |
| | 3.0-3.5 | 7A | 284HT42 | ±.25 | 30 | 4.750 | 3.19 | 3.19 | .160 | .160 |

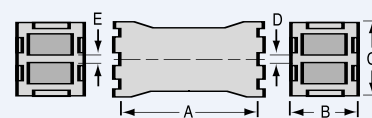
Notes: ¹ 284FT12 flange
Socket dimensions & overall tolerances shown on Page 44.

Topwall Couplers – Other than 3dB

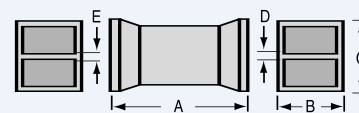
| W/G Size | Electrical Data | | | | | | Mechanical Data (inches) | | | | |
|----------|-----------------|-------|--------------|-------------------------|-----------------------------|----------------------|--------------------------|------|------|-----|-----|
| | Frequency GHz | Style | Model Number | Coupling Reference (dB) | Output Power Unbalance (dB) | Directivity (dB min) | A | B | C | D | E |
| WR51 | 16.0-17.0 | 7A | 51CE12 | 4.1 | -2.0 ±.25 | 20 | .97 | .66 | .70 | .04 | .04 |
| | 16.0-17.0 | 7D | 51CE22 | 3.8 | -1.5 ±.10 | 20 | 1.00 | .59 | .63 | .04 | .04 |
| | 16.0-17.0 | 7D | 51CE32 | 5.3 | -3.8 ±.10 | 19 | 1.00 | .59 | .63 | .04 | .04 |
| | 16.0-17.0 | 7D | 51CE42 | 6.5 | -5.5 ±.10 | 18 | 1.00 | .59 | .63 | .04 | .04 |
| WR62 | 13.0-14.7 | 7A | 62CE32 | 6.0 | -4.8 ±.25 | 15 | 1.25 | .78 | .88 | .09 | .09 |
| | 13.2-14.7 | 7A | 62CE42 | 10.0 | -9.5 ±.20 | 12 | 1.25 | .78 | .88 | .09 | .09 |
| | 15.5-18.0 | 7A | 62CE52 | 7.0 | -6.0 ±.15 | 16 | 1.11 | .78 | .88 | .09 | .09 |
| | 16.0-17.0 | 7A | 62CE62 | 7.0 | -6.0 ±.10 | 24 | 1.11 | .78 | .88 | .09 | .09 |
| | 16.0-18.5 | 7A | 62CE72 | 4.8 | -3.0 ±.25 | 20 | 1.11 | .78 | .88 | .09 | .09 |
| WR90 | 8.5-9.6 | 7A | 90CE12 | 4.8 | -3.0 ±.25 | 22 | 1.73 | 1.14 | 1.09 | .05 | .05 |
| | 8.5-9.8 | 7A | 90CE22 | 6.0 | -4.8 ±.25 | 18 | 1.73 | 1.14 | 1.09 | .05 | .05 |
| | 9.0-10.0 | 7D | 90CE42 | 7.0 | -6.0 ±.25 | 20 | 1.78 | 1.00 | 1.02 | .12 | .12 |
| | 9.09-9.66 | 7D | 90CE52 | 5.3 | -3.8 ±.30 | 20 | 1.83 | 1.00 | .95 | .05 | .05 |
| | 9.09-9.66 | 7D | 90CE62 | 3.8 | -1.5 ±.25 | 27 | 2.07 | 1.00 | .95 | .05 | .05 |
| | 9.09-9.66 | 7D | 90CE72 | 6.5 | -5.5 ±.25 | 20 | 2.60 | 1.00 | .95 | .05 | .05 |

Notes: Socket dimensions & overall tolerances shown on Page 44.

TOPWALL COUPLERS – OTHER THAN 3dB

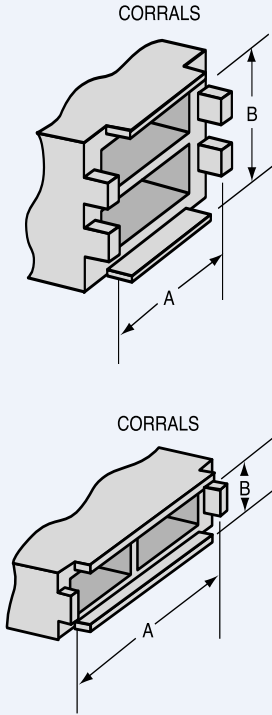


STYLE 7A



STYLE 7D

Socket Dimensions & Tolerances



| WR | ID | Common Wall Ref. | A | Tolerance -.000 | B | Tolerance B |
|----------------|-------------|------------------|-------|--------------------|-------|----------------|
| Topwall | | | | | | |
| 51 | .510-.255 | .040 | .592 | +.003 | .632 | +.003 |
| 62 | .622-.311 | .040 | .704 | +.003 | .744 | +.003 |
| | | .090 | .704 | +.003 | .794 | +.003 |
| 90 | .900-.400 | .050 | 1.002 | +.003 | .952 | +.003 |
| | | .120 | 1.002 | +.003 | 1.022 | +.003 |
| 112 | 1.122-.497 | .150 | 1.252 | +.003 | 1.274 | +.003 |
| 137 | 1.372-.622 | .074 | 1.503 | +.004 | 1.449 | +.004 |
| | | .150 | 1.503 | +.004 | 1.525 | +.004 |
| 187 | 1.872-.872 | .150 | 2.004 | +.005 | 2.026 | +.005 |
| 229 | 2.290-1.145 | .128 | 2.453 | +.005 | 2.551 | +.005 |
| 284 | 2.840-1.340 | .160 | 3.005 | +.005 | 3.005 | +.005 |

| WR | ID | Common Wall Ref. | A | Tolerance -.000 | B | Tolerance B |
|-----------------|-------------|------------------|-------|--------------------|-------|----------------|
| Sidewall | | | | | | |
| 15 | .148-.074 | .040 | .417 | +.004 | .155 | +.002 |
| 28 | .280-.140 | .040 | .681 | +.004 | .221 | +.002 |
| 42 | .420-.170 | .040 | .961 | +.006 | .251 | +.003 |
| | | .090 | 1.011 | +.006 | .251 | +.003 |
| 51 | .510-.255 | .040 | 1.142 | +.006 | .337 | +.003 |
| | | .090 | 1.192 | +.006 | .337 | +.003 |
| 62 | .622-.311 | .040 | 1.366 | +.006 | .393 | +.003 |
| | | .090 | 1.416 | +.006 | .393 | +.003 |
| MDL-B62 | .622-.138 | .040 | 1.366 | +.006 | .218 | +.003 |
| 75 | .750-.375 | .050 | 1.652 | +.006 | .477 | +.003 |
| MDL-A75 | .750-.200 | .050 | 1.652 | +.006 | .302 | +.003 |
| 90 | .900-.400 | .050 | 1.952 | +.006 | .502 | +.003 |
| | | .120 | 2.022 | +.006 | .502 | +.003 |
| MDL-A90 | .900-.200 | .120 | 2.022 | +.006 | .302 | +.003 |
| MDL-B90 | .900-.300 | .120 | 2.022 | +.006 | .402 | +.003 |
| MDL-C90 | .900-.150 | .070 | 1.938 | +.006 | .213 | +.003 |
| WR102 | 1.020-.510 | .150 | 2.318 | +.006 | .638 | +.003 |
| 112 | 1.122-.497 | .064 | 2.438 | +.006 | .627 | +.003 |
| | | .150 | 2.524 | +.006 | .627 | +.003 |
| 137 | 1.372-.622 | .074 | 2.949 | +.008 | .753 | +.004 |
| | | .150 | 3.025 | +.008 | .753 | +.004 |
| MDL-A137 | 1.372-.247 | .150 | 3.025 | +.008 | .379 | +.004 |
| MDL-B137 | 1.372-.487 | .150 | 3.025 | +.008 | .618 | +.004 |
| 159 | 1.590-.795 | .150 | 3.461 | +.008 | .926 | +.004 |
| 187 | 1.872-.872 | .128 | 4.005 | +.010 | 1.005 | +.005 |
| | | .150 | 4.026 | +.010 | 1.005 | +.005 |
| MDL-A187 | 1.872-.370 | .150 | 4.027 | +.010 | .503 | +.005 |
| 229 | 2.290-1.145 | .128 | 4.841 | +.010 | 1.278 | +.005 |
| 284 | 2.840-1.340 | .160 | 6.005 | +.010 | 1.505 | +.005 |
| MDL-A284 | 2.840-.400 | .160 | 6.045 | +.010 | .605 | +.005 |

Tolerances

Tolerances on "A" Dimension (Length)
 WR10 to WR51 = ±.005
 WR62 to WR112 = ±.010
 WR137 to WR187 = ±.015
 WR229 to WR284 = ±.020

See MDL Flange Catalog for flange dimensions and tolerances
 All dimensions and specifications are subject to change without
 notice: Contact MDL for specific dimensions and tolerances.
 All other dimensions unless otherwise specified
 reference only.