Coaxial-to-circular waveguide transition with broadband mode-free operation

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A simple transition between a circular waveguide and a coaxial cable having mode-free operation over more than an octave bandwidth is presented. The transition consists of a conical coaxial probe, a rectangular waveguide section and a linearly tapered transformer from the rectangular to circular waveguide. The transition shows a reflection coefficient of $<-20\,\text{dB}$, a transmission coefficient of $>-0.57\,\text{dB}$ and a higher-order mode level of $<-25\,\text{dB}$ over a frequency range $1.04-2.53$ times the TE$_{11}$ mode cutoff frequency.

Introduction: A broadband transition from a circular waveguide to a coaxial cable is often required in accelerator components and reflector antenna feeds. In the design of a broadband circular-to-circular transition, one is faced with two important tasks: the design of a low-reflection coaxial cable and the suppression of higher modes. Contrary to the case of a rectangular-to-circular transition, published works on the circular-to-circular transition are quite limited [1-3]. A simple coaxial probe feeding a circular waveguide shows a narrow-band performance [1, 2]. A double-ridged structure offers wideband performance although it is structurally complicated [3].

In this Letter, we present a new and simple transition between a circular waveguide and a coaxial cable. The transition consists of a conical coaxial probe, a short section of a rectangular waveguide and a linearly tapered rectangular-to-circular waveguide transition. The proposed transition is structurally simpler than the double-ridged transition [3], while offering an excellent performance.

Transition structure: Fig. 1 shows the structure of the proposed transition. It consists of a circular waveguide (w), a linearly tapered rectangular-to-circular waveguide transition (t), a short rectangular waveguide section (r) fed by a conical probe (p) and a coaxial cable (c). Fig. 1b shows a structure that can be inserted into a circular waveguide for easy fabrication.

Fig. 1 Structure of proposed transition
a Cross-section of proposed transition
b Proposed structure for easy fabrication

A direct excitation of a circular waveguide by a coaxial cable usually results in a narrow bandwidth [1, 2]. On the basis of the observation that a wideband operation is possible with a rectangular-to-circular transition [4], we first form a transition from a coaxial cable to a rectangular waveguide and then make a transition from the rectangular waveguide to the circular waveguide.

A coaxial probe combined with a single or multiple tuning posts offers a wideband operation in a rectangular-to-circular transition [4]. In the proposed transition, we employed a single conical probe for structural simplicity.

Many structures have been proposed for the rectangular-to-circular waveguide transition [5, 6]. A simple linearly tapered section is employed in the proposed transition for easy fabrication and higher-order mode suppression. The section’s length is made sufficiently large for good impedance matching and low higher mode generation.

The diameter of the circular waveguide is chosen such that the cutoff frequency of the TE$_{11}$ mode is 1.15 times smaller than the lower limit of the operating frequency. Part of the circular waveguide wall is extended to form the side walls of the rectangular waveguide section. The height $h$ of the rectangular waveguide is a critical design parameter influencing the impedance matching and the higher-order mode generation. The length of the rectangular waveguide section mildly affects impedance matching.

A simple cylindrical probe feeding the rectangular waveguide section does not offer a good impedance matching at lower frequencies. A conically shaped probe solves the problem. The taper angle and height of the probe are iteratively optimised for the best result. The distance from the probe to the transition’s back short sensitively affects the performance of the transition.

Design parameters shown in Fig. 2 are optimised in a systematic way for the best possible performance. The widely used commercial software Microwave Studio v.2012 by CST has been used in the design. As an example, for a transition operating from 7 to 17 GHz range, the following results (in millimetres) are obtained: $d_0 = 25.0$, $b = 6.65$, $d_1 = 75.0$, $d_2 = 5.99$, $d_3 = 6.73$, $d_4 = 4.76$ and $d_5 = 4.18$. The diameters of the coaxial cable’s inner and outer conductors are 1.26 and 4.10 mm, respectively, with a Teflon dielectric ($\varepsilon_r = 2.10$, tan $\delta = 0.001$) between them.

Fig. 2 Design parameters of transition

Fig. 3 shows the simulated levels of higher-order modes generated in the circular waveguide relative to the dominant TE$_{11}$ mode. All higher-order modes are below $–25\,\text{dB}$ up to $17.77\,\text{GHz}$.

Fig. 3 Levels of higher-order modes generated in transition

The performance of the proposed transition has been verified by fabrication and measurements. Fig. 4 shows two fabricated transitions of identical design, one assembled and the other disassembled. The reflection and transmission coefficients are measured using the back-to-back connection of two identical transitions with the vector network analyser HP 8720C.

Fig. 4 Fabricated transitions, one assembled and the other disassembled

Fig. 5 shows the measured reflection and transmission coefficients of the transition compared with simulated values. Above $7.34-17.77\,\text{GHz}$, the reflection coefficient is $<-20\,\text{dB}$ and the transmission coefficient is $>-0.57\,\text{dB}$. Good agreements can be observed between the measurement and simulation.

Fig. 5 Measured reflection and transmission coefficients
Fig. 5 Measured reflection and transmission coefficients of transition (solid line = simulation and dashed line = measurement)

Conclusion: A new wideband coaxial-to-circular waveguide transition is presented, which has low levels of higher-order modes generated. The performance of the proposed transition has been verified by both simulation and measurement. A sample design of the transition shows a reflection coefficient of $<-20$ dB, transmission coefficient $>-0.57$ dB and higher-order mode levels of $<-25$ dB over 7.34–17.77 GHz. The proposed transition may find applications in antennas, microwave devices and accelerator structures.

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21 July 2014
doi: 10.1049/el.2014.2667
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References