

Wideband Directional Coupling Structures Based on Ridge Gap Waveguide Technology

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Directional couplers play a crucial role in microwave and millimeter-wave systems by enabling precise directive sampling while maintaining key performance requirements such as wide bandwidth and flat coupling. Multi-hole couplers, which feature two inline waveguides coupled through their broad or narrow walls, are commonly used to achieve wide bandwidth, flat coupling, and high directivity. Cross-guide directional couplers are another widely used configuration in measurement applications. Cross-guide directional couplers offer a more compact solution and are easy to manufacture. These features promote the aforementioned topologies in a wide range of applications. However, high-frequency operation introduces several challenges, particularly in waveguide structures where maintaining proper electrical contact is crucial. Moreover, printed structure implementations of directional couplers suffer from high insertion losses, which can significantly impact system efficiency. Addressing these challenges requires an alternative host guiding structure to enhance performance while maintaining compactness and manufacturability.

Ridge gap waveguides (RGW) technology is highly recommended for high-frequency applications due to its unique ability to support quasi-TEM wave propagation within a parallel-plate-like structure. The key principle of this technology is the usage of periodic cells at the ridge level, which create an Artificial Magnetic Conductor (AMC) surface. This AMC is combined with a Perfect Electric Conductor (PEC) on the opposing surface. This results in an electromagnetic bandgap to prevent leakage and radiation losses, effectively guiding the signal along the desired path. Moreover, the most significant advantage of RGW technology is the self-isolation capability. This feature addresses a common issue faced by traditional waveguides, such as rectangular and double-ridge waveguides, which require precise electrical connections to maintain performance. By eliminating these contact requirements, RGW structures reduce manufacturing complexity, improve reliability, and minimize insertion losses. On the other hand, this technology is relatively new compared with classical guiding structures. Accordingly, many challenges are associated with deploying this technology as a host guiding structure for high directivity coupling structures. This article presents for the first time the design of cross-guide and broad-wall couplers based on RGW technology.

We present two generic solutions for high directive coupling structures based on RGW technology.

Cross-guide coupling in ridge gap waveguides (RGW) can be achieved by vertically stacking two RGW structures with their shared interface and common ground plane. The cross-guide coupler is formed by adding two cross-shaped holes and rotating the upper ridge by 90 degrees. The coupling performance can be achieved by adjusting the dimensions of the holes and the thickness of the shared ground plane. This design offers a highly stable and flat coupling response within ± 0.5 dB over the whole operational frequency range. Moreover, the coupler can achieve a directivity above 20 dB over the entire bandwidth, ensuring excellent isolation between the coupled and direct signal paths. Moreover, another coupling topology is proposed using the broad-wall technique by adding coupling holes within the common ground between two RGW structures. The proposed innovative topology has an ultra-flat coupling within ± 0.75 dB with a directivity beyond 20 dB. The presented coupler designs are featured with a compact size of $3.5 \lambda \times 3.5 \lambda \times 0.5 \lambda$.