New Low Insertion Loss Circulator
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The insertion loss of the output circulator of a power amplifier is critical. It is estimated that every 0.1dB of insertion loss at the power amplifier output costs >3W of RF power further up the chain. Engineering teams from Skyworks Solutions, Inc. and Trans-Tech, Inc. (a subsidiary of Skyworks Solutions) have successfully developed new manufacturing processes for the ferrite disk, resulting in circulator designs with industry leading insertion loss performance. The new SKYFR-000782 circulator, designed for the frequency range 2110MHz to 2170MHz, achieves a typical insertion loss of just 0.08dB. Over temperature, the insertion loss is guaranteed to meet 0.12dB maximum.

Figure 1: SKYFR-000782 image

The SKYFR-000782 is a single junction circulator in a 19 × 19 mm housing (see Figure 1), designed to operate in the standard band of 2110 MHz to 2170 MHz. This circulator can achieve insertion loss performance of better than 0.08dB at room temperature. The return loss of the three circulator ports is typically 26dB and the isolation is 28dB.
Figure 2: SKYFR-000782 insertion loss data (black) vs. insertion loss of circulator using standard ferrite (red)
Figure 2 compares the insertion loss performance of the SKYFR-000782 to a competitive unit. The competitor’s unit is designed for minimum insertion loss performance using industry-standard magnetic material. The competitive unit achieves insertion loss performance of 0.15dB versus the Skyworks’ unit insertion loss of just 0.08dB.

The key to achieving this very low insertion loss is the ferrite disk. The ferrite itself is selected with the lowest magnetic and dielectric loss garnets from Trans-Tech’s range of low linewidth magnetic materials and low loss D2000 series dielectric. Secondly, those materials are combined into a co-fired garnet/dielectric ring assembly, a patented process in which both materials are processed simultaneously and the net result is a joint with no air gap and no lossy glue. These two factors, plus the excellent transmission and reflection s-parameters of the device, combine to give the very low insertion loss performance.
Figure 4: SKYFR-000782 output return loss (s22)
Figures 3, 4, 5, and 6 show the s-parameters of the SKYFR-000782 over temperature. In addition to industry leading insertion loss performance, the isolation of the SKYFR-000782 is greater than 28dB at 25°C and 25dB over temperature. The return loss performance is greater than 25dB across the operating frequency band and temperature range.
The significant improvement in insertion loss performance of the SKYFR-000782 is the result of improved manufacturing processes of the ferrite disk and careful magnetic and electrical design in the circulator junction. This new approach allows the circulator designer to achieve insertion loss performance more than 0.05dB better than existing products. Skyworks is currently designing very low insertion loss circulators for all wireless infrastructure frequency bands.

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