

Cost and Performance benefits of cascading single junction circulators for duplex applications

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In a typical transceiver design, a circulator is often used to duplex the antenna port for simultaneous transmit and receive RF signals. Depending upon the design type and configuration of the circulator, the junction could provide isolation from 14 dB to 23 dB between any two ports. For the sake of simplicity, let's assume a 10% bandwidth span that covers both transmit and receive operational bands (example GSM800 / GSM1800 / PCS1900 / UMTS2100 / WiMAX 2.5 GHz / WiMAX 3.5 GHz). Typical insertion loss and isolation data on strip-line distributed ferrite circulators are 0.3 dB and 21 dB for operational temperature range of -40 to +85 C. When such a circulator is used at high power levels, the isolation required between the transmitter and receiver is not adequate to prevent unwanted interference.

In **Figure 1**, a single junction circulator is shown that is connected to a 100 watt transmitter and an antenna with 1.20:1 VSWR and a perfectly matched receiver. The transmit port is isolated from the RF coming back from Antenna by 21 dB. The receiver is also 21 dB isolated from the transmitter port. Hence, the receiver sees ~ 0.1 dBm of the transmit power which may cause interference problems. At this point there are a couple of options for the system designer; use a dual junction circulator or a high quality bandpass filter. While the filter performance is far superior in rejection and insertion loss, the cost and size aspects may or may not be appealing for all applications.

A dual junction circulator is shown in **Figure 2** with the transmitter shown connected to the antenna after two ferrite junctions while the receiver is connected to the common antenna through only one ferrite junction.

In this arrangement, even though it may appear that the transmitter is at a higher isolation level from the receiver, in actuality the isolation between the transmitter from any RF injected into the receive port is

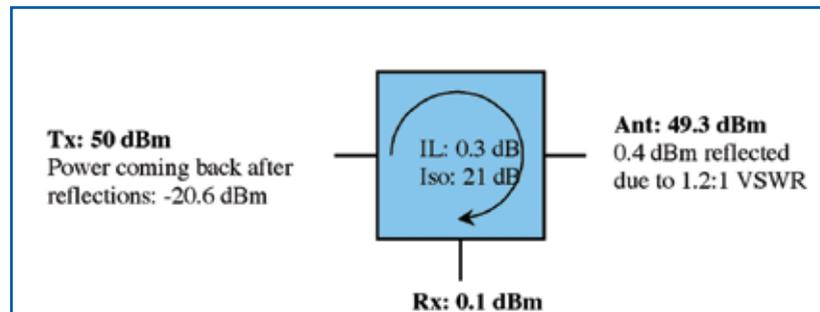


Figure 1. A single junction circulator subjected to 50 dBm of input power

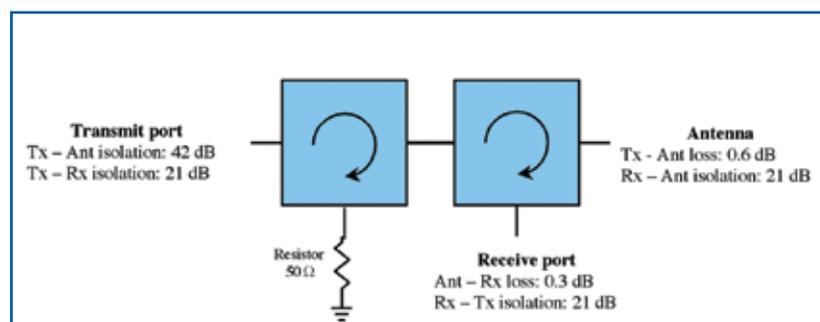


Figure 2. A double junction circulator illustrating insertion loss and isolation between various ports

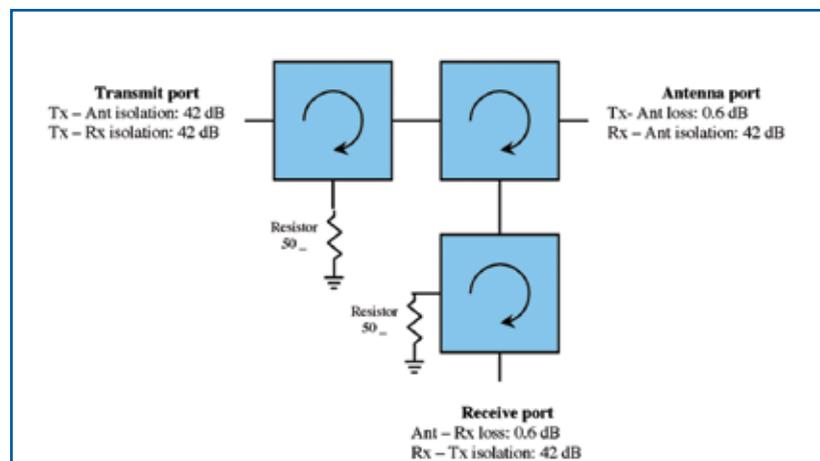


Figure 3. A tripple junction circulator is often required to provide greater isolation between the three duplexed ports

only 21 dB. This arrangement, however, provides 42 dB of isolation from the antenna port and is therefore used to protect very high power transmitters from reflected signals.

In cases where 40 dB or more isolation is required between the transmitter and receiver, three ferrite junctions are used as shown in **Figure 3**.

In the above arrangement, the RF undergoes two isolation paths when traveling in the direction opposite to the circulation. This aids in achieving much greater isolation between any two ports. However, the insertion loss between any two

ports has also increased considerably. In certain applications every tenth of a dB of insertion loss can be of concern, in which case this arrangement may not be suitable.

In real life, if the antenna port VSWR changes for some reason (technician disconnecting the antenna without turning the transmitter off), the RF will be directed toward the receive port. If there is a limiter incorporated on the receive port then the receive circuitry gets protected in this situation. However, the VSWR presented by the limiter is often not good and so the power will again be

directed back at the transmitter. In this case, the high isolation of the triple junction arrangement is the recommended configuration.

Cost of manufacturing dual and triple junction ferrite devices

Figure 4 shows mechanical layouts of single, dual and triple junction circulators. For WiMAX 2.5 and 3.5 GHz, the single junction footprint is 0.75" x 0.75". For the dual junction, the overall length increases to 1.75" while the other two dimensions remain the same. For the triple junction, the footprint increases to 1.75" x 1.75". In order to manufacture a dual or triple junction in high volume production, the following becomes labor and cost intensive issues:

1. Assembly and yield cost factor
2. Tune and yield cost factor
3. Final test

The assembly of a dual or triple junction circulator becomes more complex than a single junction circulator. Due to increased dimensions, these require more accurate aligning and holding fixtures during the first stage of assembly process. The assembly time of a dual junction circulator is 2.5 times that of a single junction. Moreover, assembly errors are more time consuming to fix in a dual and triple junction compared to single junction. If the error is beyond repair, the yield costs become significantly greater. The final tune and test process of a dual and triple junction also becomes much more time consuming than a single junction. More complex and sophisticated magnetic chargers are required to treat the magnets of dual and triple junction circulators. Therefore, the sell price of a dual and triple junction circulator becomes significantly higher than a single junction circulator.

WiMAX and Cellular Deployments

For high volume, low cost cir-

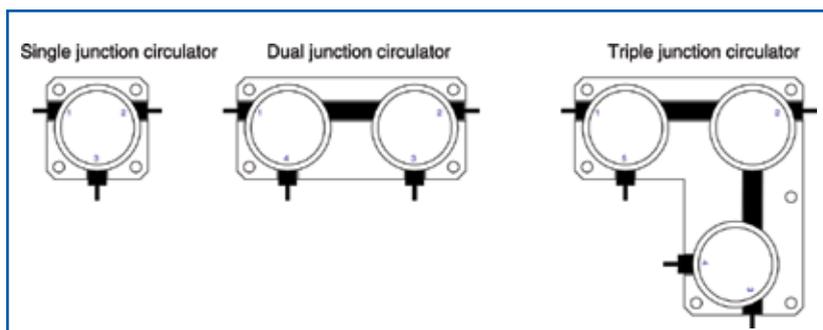


Figure 4. Mechanical Footprints of single, dual and triple junction circulators

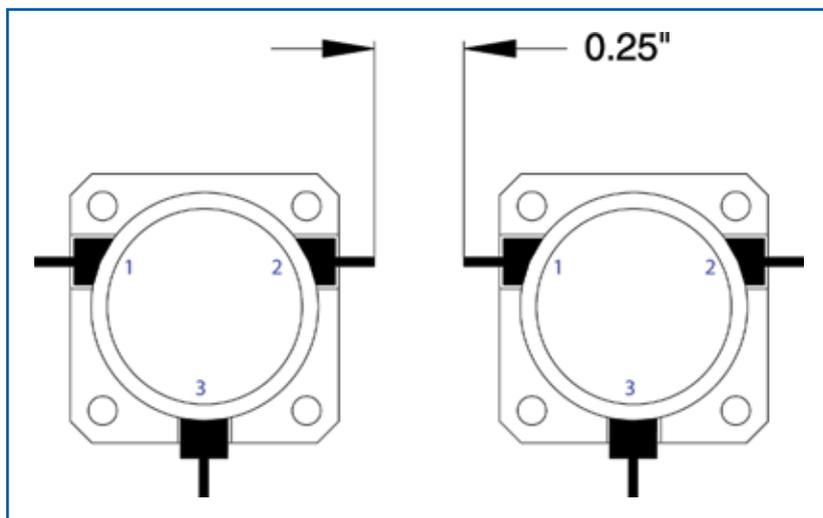


Figure 5.

culators, it becomes advisable to buy a single junction circulator and cascade it according to the system requirements rather than purchasing an expensive dual or triple junction circulator. For example, if a WiMAX single junction circulator sells for \$20, while the dual and triple costs \$60 and \$100 respectively, it makes more sense in buying more of the single junction circulators and configuring the layout to meet the loss and isolation requirements. Moreover, delivery and quality which are also critical to volume production is far superior for a single junction compared to dual or triple junction.

A good rule of thumb for all circulators is to lay them side by side so that the magnetic interaction between them is the least and space them by 0.25" as shown in [Figure 5](#).

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