Telewave.io Star Junction Combiner Tuning Procedure – Field

07/18/2023

Introduction

RF Combiners are designed to "combine" the radio frequency (RF) energy from multiple transmitters into a single feedline that carries the energy to a single "shared" antenna.

Telewave.io supports the following types of Combiners:

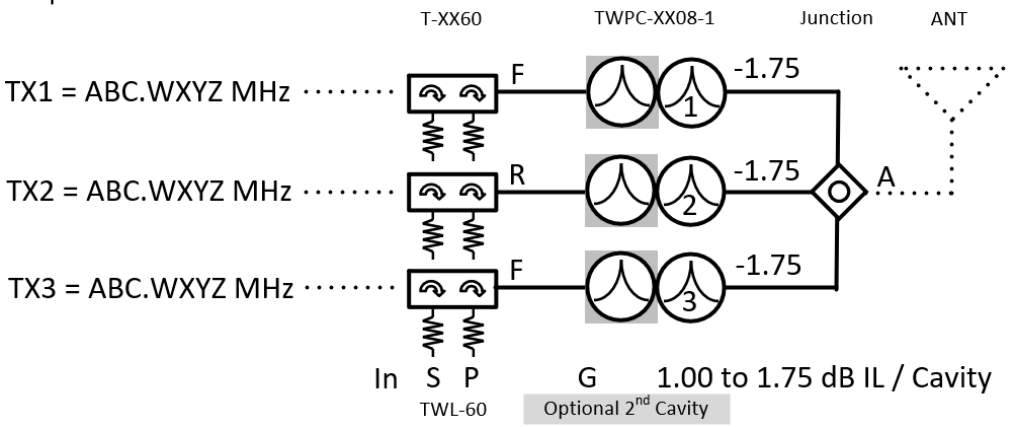
- Star Junction (including combiners that use output phase harnesses)
- Hybrid
- Combination Hybrid and Star Junction

This document discusses maintenance and tuning of the Telewave.io RF Star Junction combiners.

These combiners have 5 main components:

- **Panel** = holds the active components in place
- **Isolator** = one per channel, protects the transmitter from any energy that is flowing backward
- **Cavity** = Presents an impedance of 50 ohms at the tuned frequency & presents a higher impedance at any frequency above or below the tuned frequency (off freq. energy is reflected.)
- **Cables** = Interconnect the active components to each other
- **Junction** = Sums the energy from each channel, forwards the aggregate to the output (ANT) port

Sample Schematic:



Schematic Notes

- In = Isolator Input (connection from the Transmitter)
- S = Isolator Secondary Load (connection)
- P = Isolator Primary Load (connection)
- F/R = Isolator configuration indication (Forward or Reverse)
- G = Cavity Gate / Input (connection)
- A = Common port on the Junction (connection to the Antenna)
- There will always be at least one cavity for each combiner channel – sometimes two or more.
- For channels that use a Pass/Rej & Pass cavity, the Pass cavity must always face the Junction.
- Cables between the cavities are ¼ WL Increment "Critical" – Other cables ½ WL Increment.

www.telewave.com
1-408-929-4400
230718
sales@telewave.com
support@telewave.com

Tools Required

- Vector Network Analyzer (VNA) or Service Monitor with a Tracking Generator (SM/TG assumed.)
- Directional Coupler w/N-F connectors, suitable for the frequency range & at least 30 dB isolation.
- Infrared non-contact temperature meter.
- Telewave.io 44DL inline watt meter.
- Minimum 100 Watt coaxial 50 Ohm load
- 50 Ohm jumper cables to connect the Test Equipment to the Combiner
    - All connectors on the isolator inputs & internal connections are N-Female
    - The Junction output connector is usually N-Female, but could be DIN 7/16 or 4.3/10 F.
- Nut Driver 7/16 (11 mm)
- Open Wrench 7/16 (11 mm)
- Pliers (tongue & groove) (what size?) (Loops adjustment & loosening "too tight" coax conn.)
- Screwdriver (size #0) (Non-ferrous, non-conductive for tuning the reject on P/R cavities)
- Screwdriver (size #2) (Loops adjustment)

Important Notes

Most procedures below can only be accomplished when the Combiner is offline (not available for traffic.)

The temperature checks of the isolator loads are noninvasive and must be done before any maintenance window (outage) starts (while the system is in normal user operation.) The information gathered during the temperature check is one indication of the health of the Combining system.

Once the temperature checks are complete, then the rest of the test cases or tuning procedures can be started when the maintenance window begins.

- Teir 1 Health Check requires a maintenance window of ~ 1 hour for a typical 3 or 4 CH combiner.
- Teir 2 Health Check requires a maintenance window of ~ 1 hour per combiner channel.

Cavity tuning should be performed using a low power RF source, Tracking Generator or Network Analyzer. When transmitter power is passing through a cavity, high voltage & current exists on the internal surfaces. Tuning under power may cause internal arcing and damage.

Refer to the product Data Sheet for the specific product parameters before making any adjustments.

There are two configurations for Telwave.io Isolators – it is important to note the location of the isolators on the panel and the orientation of the loads so that any new isolator will fit in the slot.

- *Forward = looking at the isolator from the input side the loads are on the right side of the body*
- *Reverse = looking at the isolator from the input side the loads are on the left side of the body*

Other Telewave documents discuss the details of tuning isolators, cavities, duplexers and multicouplers. Additional details can be found at www.telewave.com/resources/field-tuning/.

A normal Star Junction Combiner will have a single pass cavity between the isolator and the junction, for combiners that have two or more cavities on any channel, please contact Telewave.io technical support before going to the site to do the maintenance - 408-929-4400 option 2 or email support@telewave.com.

For channel additions or frequency changes, the cavities can be pre-tuned, but the final tuning must be completed per the Teir 2 procedures (in circuit.)

All test equipment should be calibrated. Service Monitors should be normalized to the cables at the beginning of work, and anytime that test cables (jumpers) are changed.

Standard power isolators can be adjusted in the field – usually not needed (see the Isolator tuning doc.)

Medium & High-Power isolators cannot be adjusted in the field, they must be RMA back to Telewave.io for any frequency changes or adjustments.

Tier 1 Health Check (Preventative Maintenance check – PM)

This health check verifies the operation of the combiner. If the test cases pass the combiner is in good health and no other action is required.

If any isolator loads are too hot or there is excessive TX power loss, then the combiner requires additional troubleshooting and/or tuning. This is covered in the Teir 2 Health Check.

For most combiners, the power loss for each transmitter will be between 2 & 3 dB (35% & 50%). In some rare cases, there will be more than 50% loss, but this will be specified in the documentation (schematic.)

Combining losses should not change over time. The power per channel measured at the junction output should remain within a few tenths of a dB (few watts) of any previous power level measurements.

Prior to the Maintenance Window beginning (while there is normal traffic on the combiner)

- Isolator load temperature should be less than 150 degrees F.
    - Verify the temperature during normal sustained operation (before any TX shutdown)
    - Measure/record the temperature on the label at the end of each load on all isolators.
    - Check the color of all the loads, should be BLACK, not BROWN or GOLD.
    - There should not be any high VSWR or TX power level alarms on any transmitters.
- If time permits
    - Enable TX and Key all transmitters for 5 minutes, and then…
    - Measure/record the temperature on the label at the end of each load on all isolators.
    - The load temperature should remain below 150 degrees F
    - There should not be any high VSWR or TX power level alarms on any transmitters.
    - Disable all transmitters (leave disabled till instructed to enable later.)

Once the Maintenance Window has begun

- Verify TX power input and output for each channel.
    - Measure each transmitter output power level at the input to the isolator.
        - Disable all transmitters.
        - Disconnect the corresponding coax cable from the isolator input.
        - Connect a terminated power meter to the coax line.
        - Enable the transmitter.
        - Key the transmitter and measure/record the power level.
        - Disable the transmitter (leave disabled till instructed to enable later.)
        - Remove the power meter and connect the coax back to the isolator input.
    - Measure each transmitter power level at the output of the combiner junction.
        - Remove the feedline from the output of the junction.
        - Connect a terminated power meter to the junction output.
        - Enable and key each transmitter one at a time, measure/record the power level.
        - Disable all transmitters (leave disabled till instructed to enable later)
    - Compare the input and output power for each transmitter.
        - Should be no more than 50% loss for any transmitter to the Junction output
- If all test cases pass, bring the combiner back online – otherwise move to the Tier 2 procedure.
    - Connect and verify all cables from the transmitters to the combiner.
    - Connect and verify the cable from the junction output to the feedline.
    - Enable all transmitters for normal operation.

www.telewave.com
1-408-929-4400
230718
sales@telewave.com
support@telewave.com

Tier 2 Health Check (Tuning)

This procedure has two uses:

- Identifying failed components in a combiner
- Tuning of existing or newly introduced components for proper operation in the combiner

In some cases, tuning with this procedure will bring a failing combiner back to proper operation.

All Isolators should be checked before any cavities are checked and tuned.

For combiners used on trunked or public safety systems (high duty cycle), and TX power is 75 Watts or higher we recommend upgrading any 35 W isolator loads (TWL-35) to 60 W loads (TWL-60.)

While tuning the isolators or cavities the indication on the test equipment should be a smooth change as the devices are tuned. If the sweep jumps excessively while tuning, or when lightly tapping the device, or if the device will not properly tune – reach out to Telewave.io technical support - 408-929-4400 option 2.

Isolator Checks

- Disable all transmitters (leave disabled till instructed to enable later.)
- Configure the Tracking Generator to sweep from a frequency slightly below the lowest frequency to slightly above the highest frequency in use in the combiner.
- For all Return Loss tests – refer to the Directional Coupler Appendix for connection instructions.
- Primary (output side) & Secondary (input side) Load Test
    - Remove the load/s from the isolator.
    - Connect the load to the Tracking Generator via the Directional Coupler.
        - Sweep of the load should show a return loss >= 20 dB.
        - If the return loss < 20 dB = replace the load.
    - Connect the load/s back onto the Isolator body.
- Isolator Forward Insertion Loss Test
    - Disconnect the input (from the transmitter) and output (cable going to the cavity.)
    - Connect the isolator directly to the Tracking Generator
        - TG TX to Isolator input and TG RX to Isolator output
        - Should see 0.3 to 0.5 dB insertion loss per circulator stage (most Telewave.io Isolators are dual stage (thus indicating 0.7 to 0.9 dB insertion loss)
- Isolator Reverse Insertion Loss Test
    - Disconnect the input (from the transmitter) and output (cable going to the cavity.)
    - Connect the isolator directly to the Tracking Generator
        - TG TX to Isolator output and TG RX to Isolator input
        - Should see 30 to 35 dB insertion loss per circulator stage (most Telewave.io Isolators are dual stage (thus indicating 60 to 70 dB insertion loss)
- Isolator Forward Return Loss Test
    - Disconnect the input (from the transmitter) and output (cable going to the cavity.)
    - Connect the Isolator input to the Tracking Generator via the Directional Coupler.
        - Sweep should show a return loss > 20 dB.
        - If the return loss < 20 dB = Re-Tune the Isolator using the Isolator procedure.
- Isolator Reverse Return Loss Test
    - Disconnect the input (from the transmitter) and output (cable going to the cavity.)
    - Connect the Isolator output to the Tracking Generator via the Directional Coupler.
        - Sweep should show a return loss > 20 dB.
        - If the return loss < 20 dB = Re-Tune the Isolator using the Isolator procedure.

Connect all cables from the Isolator back to the cavities and to the transmitters (keep TX disabled.)

www.telewave.com
1-408-929-4400
230718
sales@telewave.com
support@telewave.com

Cavity & Junction Checks

Cavities will interact with each other when connected in a network such as a combiner (junction), a duplexer (phasing harness) or a window filter (in line.) Due to the interaction all cavities must first be course tuned individually, and then fine tuned together in the network.

A normal Star Junction Combiner will have a single pass cavity between the isolator and the junction, for combiners that have two or more cavities on any channel, please contact Telewave.io technical support before going to the site to do the maintenance - 408-929-4400 option 2 or email support@telewave.com.

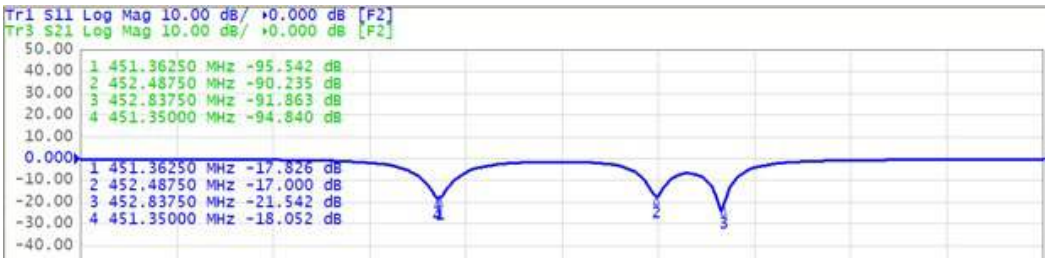
The frequency fine tune and the setting of the insertion loss (setting the Q or TX-TX isolation) for each channel (cavity) are interactive… one may affect the other. The insertion loss and the frequency setting may need to be done more than once to get the entire network balanced and working properly.

- Disable all transmitters (leave disabled till instructed to enable later.)
- Configure the Tracking Generator to sweep from a frequency slightly below the lowest frequency to slightly above the highest frequency in use in the combiner.
- For all Return Loss tests – refer to the Directional Coupler Appendix for connection instructions.

- Individual Pass Cavity Tune
  - Isolate the cavity from the Isolator and the Junction
  - Connect the cavity directly to the Tracking Generator
  - the locking nut on the center tuning shaft.
  - Turn the tuning rod slowly (left/right) till the pass is centered at the target frequency.
  - Tighten the locking nut, just enough to hold the rod on frequency.
- Tune the Insertion Loss (typical 0.5 to 2.0 dB / cavity @ resonance – see schematic for expected)
  - Loosen the retaining screws around the loop connector, just enough to rotate the loop.
  - Rotate the loop slowly (left/right) until the desired insertion loss and/or the desired isolation at a particular number of KHz or MHz from the primary frequency is indicated.
  - Snug the loop/connector retaining screws, just enough to hold in place.
- Reconnect the Cavity to the Isolator and the Junction.
- Do the course tune for the rest of the cavities on the combiner.

Fine (in Network) Tune

- Disable all transmitters (leave disabled till instructed to enable later.)
- Configure the Tracking Generator to sweep from a frequency slightly below the lowest frequency to slightly above the highest frequency in use in the combiner.
- Disconnect the feedline from the junction output.
- Connect the Junction output to the Tracking Generator via the Directional Coupler (see appendix)
- Check for a Return Loss “dip” of >=18 dB for each frequency (each cavity) in use on the combiner.



- Fine tune the pass frequency of any cavity that is off frequency (see steps above.)
- Slightly reduce the insertion loss for any cavities that indicate < 18 dB Return Loss.

Closely spaced frequencies or frequencies in the middle of the set in the combiner network will show less Return Loss than frequencies that are spread widely from each other or are on the upper/lower edge.

TX-TX Isolation Check

- Disable all transmitters (leave disabled till instructed to enable later.)
- Configure the Tracking Generator to sweep from a frequency slightly below the lowest frequency to slightly above the highest frequency in use in the combiner.
- Disconnect the feedline from the junction output.
- Connect the Tracking Generator TX directly to the Junction Output.

- For each Cavity (channel) in combiner
    - Connect the Tracking Generator RX to the Cavity (channel) input.
    - See that there is >=13 dB of isolation to any adjacent frequency in use on the combiner.
    - If the isolation is too low, dial in slightly more insertion loss for that cavity

- Tune the Insertion Loss (typical 0.5 to 2.0 dB / cavity @ resonance – see schematic for expected)
    - Loosen the retaining screws around the loop connector, just enough to rotate the loop.
    - Rotate the loop slowly (left/right) until the desired insertion loss and/or the desired isolation at a particular number of KHz or MHz from the primary frequency is indicated.
    - Snug the loop/connector retaining screws, just enough to hold in place.

- If make any insertion loss corrections; Re-check the Fine In-Network tune (see steps above.)

Cleanup

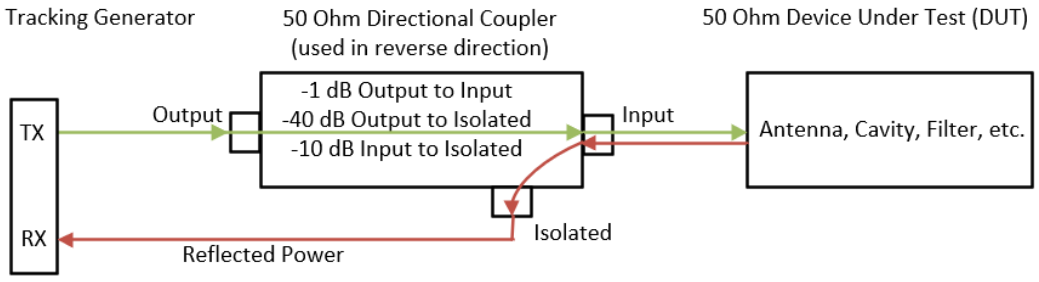
- While the combiner is still connected to check the Return Loss Sweep of the combiner.
- Verify that all cables from the cavities to the junction are connected and tight.
- Verify that all cables between the isolators and the cavities are connected and tight.
- Verify that all cables from the transmitters to the isolators are connected and tight.
- Verify that all three loop screws on all cavities are tight (hold loop in place while tightening.)
- Verify the tuning lock nuts on all cavities are tight (hold the tune knob in place while tightening.)
- Verify that the Return Loss Sweep still looks good.
- Disconnect the Test Equipment from the Junction output.
- Connect the feedline to the Junction output.
- Enable all transmitters (back to normal system operation.)
- Procedure is complete!

Contact Telewave.io technical support if you encounter any issues with any combiner procedures.
408-929-4400 option 2 or email support@telewave.com

Appendices

Return Loss measurement using a Tracking Gen & Directional Coupler

- Connect the test equipment and Device Under Test (DUT) per the diagram below.
- For devices that have two or more ports, the unused ports must be terminated with 50 Ohm loads.
- Sweep the DUT from just below to just above the frequencies of interest.
    - This includes frequencies that are intended to be passed, as well as important frequencies to be blocked.
    - For combiners this should include all TX frequencies to verify TX to TX isolation, and in some cases RX frequencies to confirm adequate sideband protection.
- In the example below, the Return Loss = ((TX level dB – RX level dB) + 10 dB)



Single Cavity Generic Rules

- Single Pass Cavities = Return Loss >=18 dB in both directions
- Single Pass Cavities = Insertion Loss (IL) range from 1 dB to 2 dB Maximum
- Multiple Pass Cavities = Return Loss >=14 dB in both directions
- Multiple Pass Cavities = IL range per network from 1 dB to max IL 1.5 dB times number cavities

Multiple Cavities (in a network) Generic Rules

- Tune the cavities individually, and then tune together in network (with the jumper/s between)
- The cable between cavities should be a ¼ wavelength increment.

<><><><>

www.telewave.com
1-408-929-4400
230718
sales@telewave.com
support@telewave.com