

Anyone responsible for a multiple-site, multiple-channel land mobile radio communications system knows that management of even just a single site can often be a complex task. Failures or degradation in performance are often initially reported by end users, but multiple trips to the site may be necessary to fully diagnose and correct the issue. For sites that are located in remote areas with low accessibility, a small failure can become a major hassle, requiring an extensive time and monetary investment.



*3141 Channel Power Monitor Display, 4044 Non-Directional Power Sensor and 4043 Directional Power Sensor*

Fortunately, Bird has developed the Model 3141 Channel Power Monitor system specifically to address the complexity of land mobile radio system management. The Bird CPM system integrates high-quality, yet inexpensive, power monitoring equipment into a single reporting system capable of providing feedback through the internet via integrated web software or SNMP messages. This system enables a single manager to measure and track the performance of their LMR sites over time, without ever leaving the comfort of their desk. With thoughtful placement of integrated sensors, a manager can even diagnose most aspects of a full radio and combiner system without ever visiting the site, ensuring that one has everything needed to correct the issue on the very first trip.

### *Components of a CPM Integrated Combiner System*

The power and versatility of the Bird Model 3141 Channel Power Monitor system comes from the great breadth of information that can be gathered and consolidated from the output of multiple low-cost sensors. By placing sensors in specific points within a combined multiple channel land mobile system, one can diagnose the radios to the output antenna and all points in between.

A typical land mobile radio system with a Bird T-Pass Combiner system is shown in Figure 1. Figure 1 is similar to those shown in the CPM manual, with finer details of the T-Pass Combiner system included in the diagram. The individual components are described in more detail below.

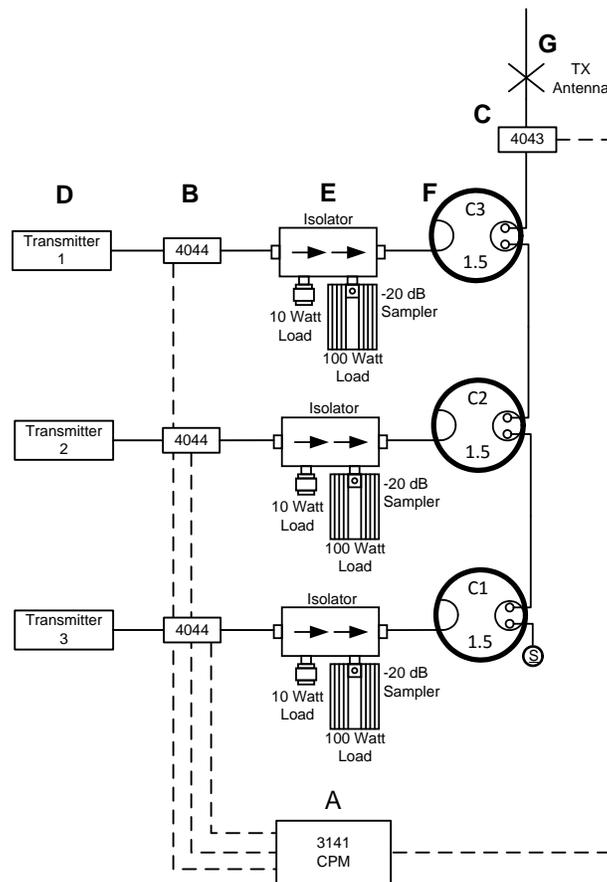


Figure 1 - CPM Integrated in T-Pass Combiner System

**Component A of Figure 1** shows the CPM system. The CPM is itself a monitoring and reporting system; it collects data from its attached sensors via a data cable and then logs and reports that aggregated data via its front panel, web interface, SNMP traps, or alarm contacts. This is the primary interface that a user interacts with to observe the status of the overall system. The specific setup and operation of the CPM is covered in extensive detail in the *Installation and Operation Manual for the Model 3141 Channel Power Monitor*, manual number 7-9587.

The CPM reads system status information directly from sensors installed in the system. Currently two such sensors are supported by the CPM system, the Model 4044 Non-Directional Power Sensor and the Model 4043 Directional Power Sensor. Additional sensor types are being developed for specific power measurement applications.

**Component B in Figure 1** shows the recommended position of the Model 4044 Non-Directional Power Sensor. The 4044 is a small, low-cost sensor that provides a power measurement regardless of which port the power is being injected. Since it is a non-directional sensor, it can only provide a general forward power measurement, and does not provide reverse power or VSWR reading.

The accuracy of the 4044 forward power measurement is dependent on its being well matched to its system. In other words, it requires a high return loss, and thus a low ratio of power being reflected back at the sensor. For this reason, the 4044 power sensor is usually installed before the combiner isolator (Component E on Figure 1), and will only allow power to flow toward the antenna and not back toward the transmitter. When the 4044 is installed in this position, the isolator provides a high return loss for the sensor, while isolating the 4044 from the other transmitters on the combiner system.

This configuration results in the power reading from the 4044 being a highly accurate representation of the power being produced by the transmitter itself. It does not, however, provide a measurement of how much power may be reflected back toward the transmitter. As the 4044 is an inexpensive sensor, it is recommended that one be installed for each transmitter in the system. This allows a user to quickly verify whether a particular transmitter is producing the expected power output.

**Component C in Figure 2** shows the recommended position within the overall system of the Model 4043 Directional Power Sensor. The 4043 is a more advanced cousin of the 4044 sensor. It is directional in nature and can differentiate between powers detected on each port of the sensor. It can provide a forward power reading, reverse power reading, and VSWR reading. Unlike the 4044 sensor, the 4043 sensor is accurate regardless of the matching of the network and can provide accurate readings even if there is a complete break in the transmitter path. This makes the 4043 ideal for characterizing the antenna and feedline path regardless of path quality.

Because the 4043 is more powerful than the 4044 it is generally installed to characterize the combined antenna path of the system. In this position it can analyze the quality of the antenna path via its VSWR measurement. It can also provide a forward power measurement for comparison against the transmitter-specific 4044 sensors, as a means of characterizing overall combiner performance.

The rest of the components on the diagram make up the overall combiner/radio system into which the CPM system integrates.

Component D represents the actual radio transmitters that will ultimately be combined into a single transmitter antenna network.

**Component E in Figure 1** is the previously mentioned dual isolator, a standard and necessary component of a combiner system. The dual isolator is used to create an RF diode which only allows RF energy to flow out toward the antenna system and not toward the transmitter. The isolator provides for directionality in the system and diverts any RF power reflecting back from the combiner to a load, instead of back to the transmitter. By creating directionality in the system, it protects the radio transmitters from a high reflected power, either due to a poor match on the antenna system, or a poor match due to tuning issues in the combiner. It also provides additional transmitter to transmitter

isolation, effectively preventing transmit energy from feeding through one port of the combiner and back out an adjacent port. In doing this, the isolator serves a secondary purpose of ensuring that the only RF energy for a particular transmitter reaches a particular 4044 sensor, ensuring accuracy of the 4044 sensor's measurement.

Component F of Figure 1 shows the cavities that make up a standard T-Pass combiner system. The cavities provide TX to TX isolation, clean up noise in the transmitter signals, and ultimately combine the transmitter signals onto a single line. Note that the T-Pass configuration shown is the most basic T-Pass setup: one cavity per transmitter. In an actual T-Pass combiner deployment, there may be multiple cavities per channel, each cavity adding additional filtering to the system to clean up the noise response of the transmitter.

Finally, Component G in Figure 1 shows the antenna and feedline of the combined radio system. The 4043 sensor is positioned so that it provides VSWR measurements for the antenna and feedline quality.

## *Analyzing CPM Measurements*

The Bird Model 3141 Channel Power Monitor system is designed to keep a constant eye on the status of a land mobile radio system. To this end, a user can observe system power measurements in real time, review power measurements from a rolling log database, or even configure the CPM to report alarm conditions as they occur. In most cases, the user will not interact with the CPM on a regular basis, only looking more deeply into recorded CPM data in response to a generated alarm condition. To this end, the position of the various 4044 and 4043 sensors within the system allow for quick diagnosis of certain components of the system, while diagnosis of other components may require a little more data analysis on the part of the user.

## *Transmitter Power Output*

In the standard combiner system setup, there is a 4044 sensor installed on the output of each transmitter. This 4044 sensor can be used to verify that the power being produced by a particular transmitter is in fact the full expected power of the transmitter. If the expected power is not seen in this reading, this can indicate a failure condition within the transmitter itself, thus indicating to a deployed field tech that a replacement or repair of the transmitter may be appropriate. Figure 2 shows an example of transmitter energy flowing through a system, and the point at which the forward power should be read. The measurement provided by the 4044 verifies that the transmitted power is at the expected level. A measured power level below the expected may indicate a failure condition within the transmitter. A deployed field tech could then use this information to determine if a replacement or repair is appropriate.

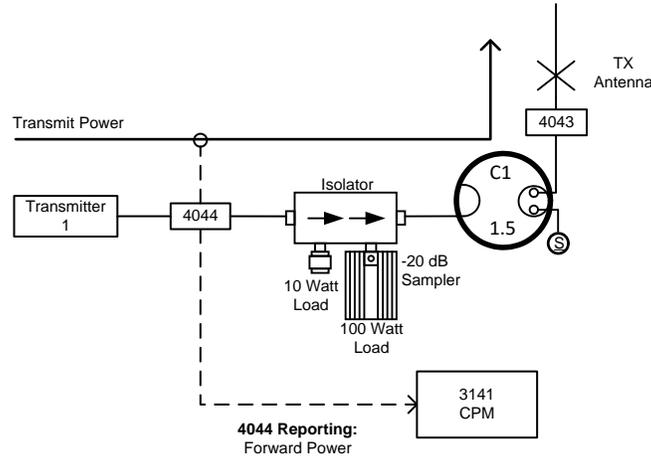


Figure 2 – Individual Transmitter Power Measurement

To analyze the status of a particular transmitter check the measurement from the 4044 sensor when the transmitter is keyed. If the transmitter is part of a repeater, this could be as simple as keying up a handheld radio for that particular channel and verifying that the CPM display shows the output power expected from the transmitter into the combiner.

Because this is a simple measurement and does not require any advanced analysis, an alarm can easily be set up to detect a transmitter failure condition. Specifically, the 3141 provides a minimum forward power alarm. A threshold for minimum power can be set to slightly lower than the expected power level and then alarm when the transmitter may be failing. Reference the *Installation and Operation Manual for the Model 3141 Channel Power Monitor*, manual number 7-9587 for more details.

Furthermore, one can use the data exporting feature of the CPM interface to export all sensor readings on a minute by minute basis into a comma delimited file. This can then be imported into a spreadsheet program such as Microsoft Excel and graphed, showing the progression of the transmitter failure over time.

### Antenna and Feedline Performance

Another component of a combiner system that is fairly simple to analyze and flag via generated alarms is the quality of the combined transmitter feedline and antenna. Since the 4043 sensor can differentiate between power detected on each of its ports, it can accurately calculate a VSWR measurement, indicating whether the antenna system and the combiner system are well matched. If the VSWR becomes particularly high, this can indicate a break in the feedline, failure of the antenna, or even declining quality of either component. Because this is a fairly simple measurement with a direct correlation to the quality of the antenna and feedline, alarm conditions can easily be set and data over time analyzed using the same techniques described in the previous section. See Figure 3 for details on the flow of energy through the system and the sensor point for collecting feedline and antenna VSWR data.

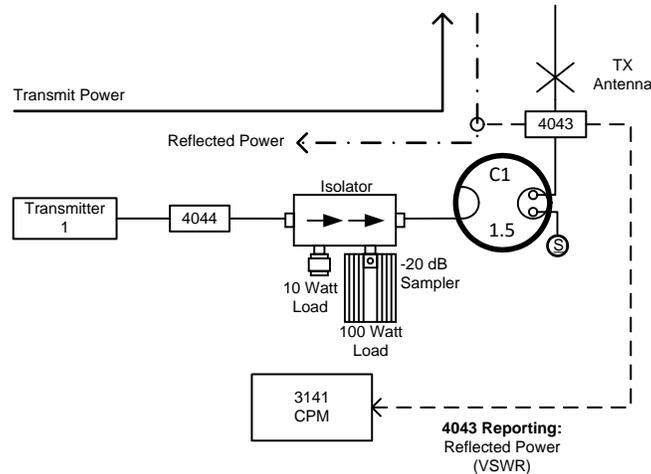


Figure 3 – Composite VSWR Measurement

One point to note regarding the 4043 sensor: the 4043 is a composite power sensor. This means that it does not measure power by individual frequency channel, but measures all power present on the line. So while during normal operation the VSWR measurement should stay fairly consistent, it is possible to see much greater variation in forward and reflected power readings as varying numbers of transmitters in the system turn on and off. As a result, it may be quite difficult to apply a meaningful alarm based on the 4043 sensor forward power reading. The forward power reading from a 4043 can, however, prove very useful as a point of comparison with the readings from the transmitter specific 4044 sensors, as outlined in the next section.

### *Combiner Performance - Cavity Tuning and Drift*

Bird T-Pass Cavity Combiners are designed to combine transmitter signals with minimal insertion loss and high degree of adjacent channel isolation while maintaining the highest quality of transmitter noise suppression. T-Pass combiners are comprised of multiple frequency-tuned temperature-compensated cavity filters, which are inherently low loss and can handle high power without drifting in frequency. Inherently robust, many T-Pass systems are still deployed and active even after thirty years of operation. As failures in T-Pass cavity combiners are extremely rare, usually only seen in cavities that have been retuned year after year to accommodate changing sites, it's very unlikely that a cavity would need to be replaced on a site.

A typical challenge presented to the field technician when on a service call to the site, is to determine whether or not the combining system is performing as expected or if there is another cause for a RF power problem at the site. The CPM can be a very valuable troubleshooting tool to the service technician while on site, or even better yet, before traveling to a distant site. By comparing data between the 4044 and 4043 sensors, it is possible to eliminate the cavity combiner entirely as a source of issues if detuning or cavity drifting is suspected.

Problems with a T-Pass combiner can be identified and characterized by comparing the power measurement from a particular transmitter's associated 4044 sensor with the forward power measurement reading on the 4043 sensor at the antenna port of the combiner. If a 4044 sensor is showing that the full expected power is being emitted by the transmitter, but the forward power of the 4043 sensor is showing a lower than expected power reaching the antenna port, then there may be something in the transmitters T-Pass combiner leg attenuating the signal. This can be determined by making sure only the transmitter of interest is keyed and then observing the power for that single channel as read by the 4043 sensor at the output of the combiner. The observed RF power loss per channel can be compared to previously recorded data. See Figure 4 for an example of the transmit path and which data points are compared to characterize combiner performance.

One of the tremendous benefits provided by the CPM is remote webpage access to observe these measurements. The field service person can be remotely located while observing the webpage data, and then key-up individual channels of interest using a handheld radio and make an instant determination of whether or not the combiner is performing as expected by observation of the power measurements shown on the CPM webpage. This can help the technician be better prepared with information and equipment prior to heading out to a site or avoid unnecessary trips to the location all together.

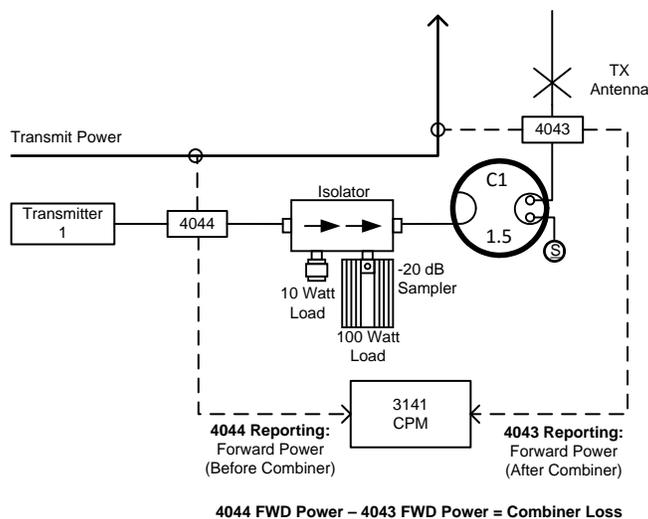


Figure 4 – Combiner Characterization through Forward Power Comparison

To perform this comparison, one first would want to export the continuous data collected by the CPM into a comma-delimited file, for further processing in spreadsheet software like Microsoft Excel. Once the data is available in Excel, it should be filtered such that the only entries analyzed are those where the particular transmitter's 4044 sensor is showing power, with *no other 4044 sensors showing an active transmitter*. If more than one 4044 sensor shows that a transmitter is active, then the forward power reading on 4043 would be a composite of the multiple transmitters' power, and provide a misleading point of comparison. When only records showing just the transmitter of interest being active are visible,

then a user can subtract the expected loss of the combiner (usually provided as dBs on a supplied combiner diagram) from the forward power reading of the 4044 sensor and compare the result to the forward power of the 4043 sensor. For example, if a particular 4044 sensor shows 100W going through the channel and the combiner leg has 3.0 dB of loss (indicating half of the power is lost through the combiner), one would expect to see roughly 50W of forward power being detected by the 4043 sensor. If there is significantly less power detected by the 4043 sensor, it is possible that a failure or detuning in the combiner leg is contributing to the additional loss.

Once the CPM data is imported into a spreadsheet program and records where more than one channel active at a time is hidden from the data set, a user can effectively track any increases in channel loss over time. This is done by creating a new column in the spreadsheet with the dB difference between the 4044 forward power and the 4043 power. Any changes in loss, and by association drift in a cavities tuned frequency, could be attributed to heating issues within the radio shelter, or with failure of the cavities temperature compensation mechanism.

### *Combiner Performance – Isolator Performance*

While the cavities in Bird T-Pass Combiners are inherently robust, the isolators that further protect transmitters from high power can be more susceptible to failure. Under normal operation an isolator's primary function is to provide additional transmitter to transmitter isolation, preventing multiple high power signals from mixing within transmitter amplifiers. Additionally, the isolator protects high reflected energy from feeding back into a transmitter, as might occur in a failed antenna or transmission line. If an isolator receives more power than it is rated to handle, either from high reflected power or high power transmitters on site, it may fail.

Luckily this can easily be detected through further analysis of CPM measurements. An isolator can fail in a variety of ways, depending on its construction. If an isolator fails closed, that is the isolator is adding additional attenuation to the T-Pass leg, it is possible to detect this using the same technique as discussed in the previous section.

However, many times an isolator will continue to pass a signal in the forward direction, but not provide the same level of reverse flow protection. In this case, any power that is directed back toward the isolator passes uninhibited to the transmitter, rather than being restricted as in normal operation. Such an error condition can be easily detected by comparing the power levels detected by adjacent transmitter's 4044 sensors. If one transmitter is keyed up and a second transmitter's associated 4044 sensor shows a significant bump in detected energy, despite the second transmitter not being keyed, this may indicate a failed isolator on the second transmitter's T-Pass leg. This is because the cavities in a combiner system usually only provide a minimal amount of TX to TX isolation, as low as 7 dB depending on TX frequency spacing, with the bulk of TX to TX isolation, 50 to 60 dB, being provided by the isolator. Any energy making it back through the failed isolator would only be moderately attenuated and still be detectable by a 4044 sensor. See Figure 5 for an example of the transmit energy path through a failed isolator and the data points of interest.

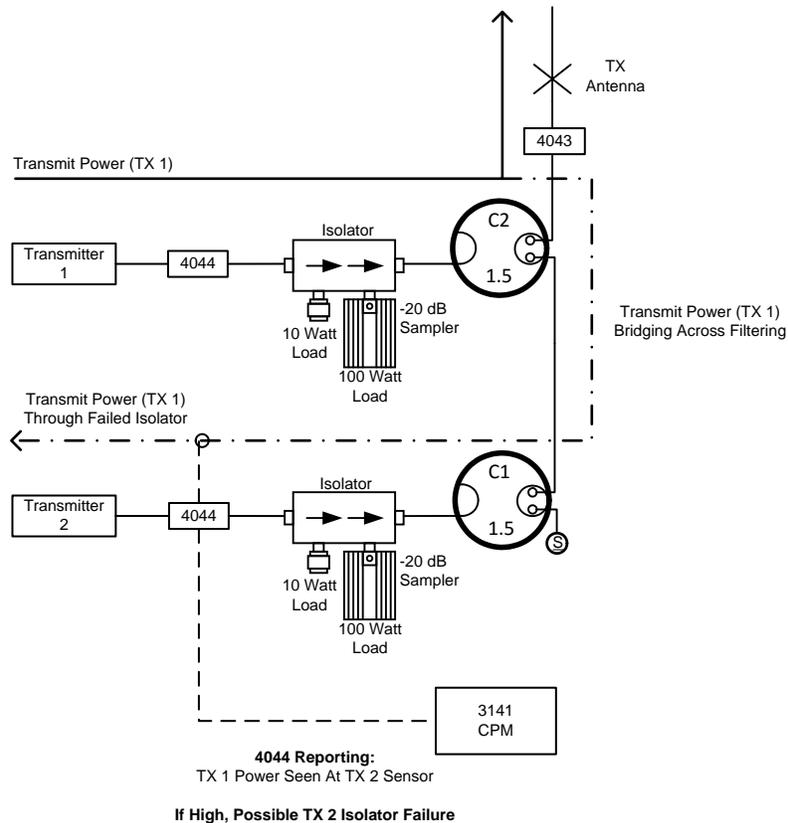


Figure 5 – Isolator Characterization through Adjacent Transmitter 4044 Sensor Data

## High Performance for Minimal Cost and Effort

Bird developed the Model 3141 Channel Power Monitor system to address the increasing complexity of the land mobile radio system management task. A low cost, and highly scalable solution, the CPM is an excellent complement to any of Bird highly dependable T-Pass combiner systems. Though programmable alarm reporting, advanced data logging, and at-a-glance diagnostics, Bird provides a system that enables a manager to guarantee smooth operation of any size public safety network.

[Channel Power Monitor System](#)