APPLICATION NOTE

Monitoring Complex LMR Systems Using Ethernet RF Sensors

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Managing multi-site, multi-channel land mobile radio (LMR) systems is inherently complex. Performance degradation often develops gradually and is not immediately visible during routine site visits, leading to delayed diagnosis, reactive maintenance, and unnecessary truck rolls.

This application note explains how Ethernet RF power sensors can be strategically deployed within LMR systems to provide continuous visibility into transmitter output, combiner performance, and antenna/feedline health. Real-world placement examples and measurement analysis techniques are presented to show how system issues can be identified remotely, often before users are impacted.

In this application note, you'll learn how to:

- Place Ethernet RF sensors within complex LMR systems for maximum diagnostic value
- Monitor transmitter output, combiner performance, and antenna/feedline health remotely
- Interpret sensor measurements to identify developing issues before site visits are required

Bird Ethernet RF Power Sensors

To support continuous, remote monitoring in complex LMR environments, Bird offers a family of Ethernet RF power sensors designed for direct, in-line installation within the RF signal path (**Figure 1**). Using standard Ethernet connectivity with web-based and SNMP reporting, the sensors provide real-time visibility into transmitter output, combiner performance, and antenna/feedline health.

Figure 1: Ethernet sensor options provided by Bird.

The following sections show common sensor placement points in a typical LMR system and explain how measurements from each location can be used to diagnose developing performance issues.

Components of a Remote Power Sensor-Integrated Combiner System

The value of Bird Remote Power Sensors comes from the breadth of measurement data that can be gathered from multiple sensor points and consolidated into a single view. By placing sensors at key locations within a multi-channel LMR combiner system, operators can diagnose performance from each **transmitter** through the combiner and feedline to the antenna—isolating issues anywhere along the RF path.

A typical land mobile radio system with an example T-Pass Combiner system is shown in **Figure 2.**

Component A in Figure 2 shows the recommended installation point for the **Model 4042E Channel Power Sensor** at the combined transmit output ahead of the antenna. The 4042E is an **in-line, directional** sensor that provides **forward power, reflected power, and VSWR** measurements. In multi-channel combiner systems, it can be configured to scan up to 16 channels (user-defined frequency and selectable channel bandwidth) to report per-channel measurements and aggregate (composite) forward/reflected/VSWR derived from the sum of actively transmitting channels (Component D).

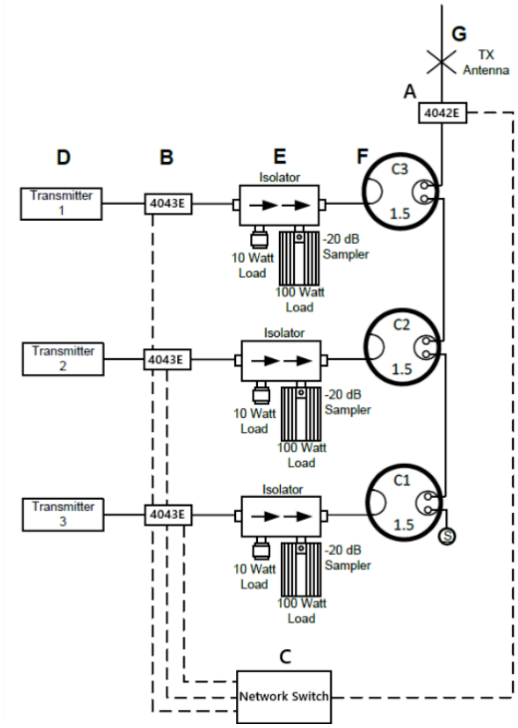

Figure 2: Remote Power Monitor sensors integrated in a T-Pass combiner system.

See **Figure 3** for an illustration of the web interface with six channels defined. This makes the 4042E well-suited for characterizing antenna and feedline performance regardless of path quality.

Sensor Name: 4042E-SITE-A

Forward 19.5 W Max Alarm
Reflected 0.0 W
VSWR 1.05
Temperature 57.6 °C
Uptime 77:04:35:50

Channel Name	Forward Power	Reflected Power	VSWR	PTT State
C1 Alpha 465	4.1 W	0.0 W	1.1	Disabled
C2 Bravo 465.5	3.6 W	0.0 W	1.1	Disabled
C3 Charlie 466	0.0 W	0.0 W	1.0	Disabled
C4 Delta 466.5	0.0 W	0.0 W	1.0	Disabled
C5 Echo 467	5.5 W	0.0 W	1.1	Disabled
C6 Foxtrot 467.5	6.3 W	0.0 W	1.0	Disabled

Figure 3: A 4042E sensor configured to monitor six individual transmitter channels.

Because the 4042E offers additional measurement capability compared to the 4043E, it is generally installed to characterize the combined antenna path of the system. In this position it can evaluate the quality of the antenna path via its VSWR measurement. It can also provide a forward power measurement for comparison against the transmitter-specific 4043E sensors (as positioned in Figure 2), as a means of characterizing overall combiner performance.

Component B in Figure 2 shows the recommended position of the **Model 4043E Directional Power Sensor**. The 4043E is a more cost-effective sensor that provides forward and reflected power measurements but is intended for a single pre-defined frequency range. For this reason, the 4043E power sensor is usually installed before the combiner isolator (Component E in Figure 2).and will only allow power to flow toward the antenna and not back toward the transmitter. When the 4043E is installed in this position, the isolator provides a high return loss at the sensor location while isolating the 4043E from the other transmitters on the combiner system.

This configuration results in the power reading from 4043E being a highly accurate representation of the power produced by the transmitter. It is recommended that a 4043E be installed for each transmitter in the system. This allows the user to quickly verify whether a specific transmitter is producing the expected output power.

The rest of the components in the diagram represent the overall combiner/radio system into which the Ethernet sensors are integrated.

Component E in Figure 2 is the previously mentioned dual isolator, a standard and necessary component of a combiner system. The dual isolator acts as a one-way device in the RF path—passing forward RF energy toward the antenna system while routing reverse (reflected) energy to an internal load rather than back toward the transmitter. By establishing this effective directionality, it protects the radio transmitters from high reflected power that can result from antenna mismatch or combiner tuning issues.

The isolator also provides additional transmitter-to-transmitter isolation by preventing transmit energy from coupling through the combiner and appearing at adjacent ports. In doing so, it helps ensure that each 4043E sensor primarily measures RF energy from its associated transmitter path, supporting accurate transmitter-specific power readings.

Component F of Figure 2 shows the cavity filters that make up a standard T-Pass combiner system. These cavities provide transmitter-to-transmitter (TX-TX) isolation, filter out-of-band emissions and broadband noise, and combine multiple transmitter outputs onto a single feedline. Note that the T-Pass configuration shown is the most basic setup—one cavity per transmitter. In an actual T-Pass 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.

Component C of Figure 2 shows the network switch system. The Ethernet sensors themselves serve as the monitoring and reporting layer: they collect measurement data from their installed location within the RF system and report that data via an individual web interface, SNMP (including traps), or—in the case of the 4042E-PTT—alarm contacts. Detailed configuration and operation, including measurement setup and SNMP alarm settings, are covered in the respective sensor manuals.

At the system output (Component G in Figure 2), the antenna and feedline represent the final RF path to the site antenna. 4042E is positioned to provide VSWR measurements that indicate antenna/feedline match quality.

Analyzing Remote Power Monitor Measurements

Bird Ethernet sensors are designed to provide continuous visibility into the operating status of an LMR system. Users can view power measurements in real time and configure alarms to report abnormal conditions as they occur. In most deployments, users do not interact with the sensors daily; instead, they review measurements and logged conditions after an alarm is triggered.

Sensor placement within the system—using 4042E, 4042E-PTT, and 4043E sensors at key points—enables fast identification of many common issues. Some conditions can be diagnosed immediately based on where the change is observed, while others may require deeper analysis of trends and measurements across multiple sensor locations.

Transmitter Power Output

In a standard combiner system, a 4043E sensor is installed at the output of each transmitter. This sensor verifies that the transmitter is producing the expected forward power. If the measured power is below the expected level, it may indicate a fault or degradation within the transmitter, signaling that service or replacement may be required.

Figure 4 illustrates transmitter energy flowing through the system and the point at which forward power is measured. The 4043E reading provides a quick confirmation that each transmitter is operating at the expected output power and helps identify underperforming transmitters before a site visit is completed.

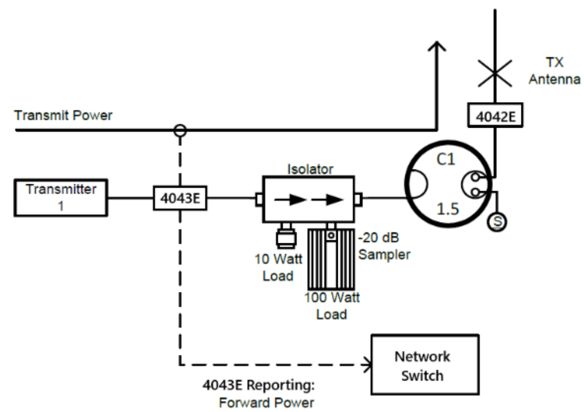

Figure 4: Individual transmitter power measurement.

To evaluate the status of a particular transmitter, check the 4043E measurement while the transmitter is keyed. If the transmitter is part of a repeater system, this can be as simple as keying a handheld radio on that channel and verifying in the sensor's web interface that the measured forward power matches the expected transmitter output into the combiner.

Because this is a straightforward check and does not require advanced analysis, an alarm can be configured to detect transmitter under-power conditions. The 4043E supports a **minimum forward power** alarm. Set the minimum forward power threshold slightly below the expected operating level to flag abnormal reductions in transmitter output.

Figure 5: The 4043E can have both minimum and maximum power thresholds to issue alarms against.

Antenna and Feedline Performance

Another combiner-system component that is straightforward to evaluate—and to flag using alarms—is the combined transmitter feedline and antenna path. Because the 4042E can monitor each defined channel within the combined signal, it can calculate VSWR for the antenna/feedline path and indicate whether the system remains well matched. If VSWR becomes elevated, it may indicate feedline damage, connector/cabling degradation, antenna failure, or a developing mismatch condition.

Because VSWR has a direct correlation to antenna/feedline match quality, alarm thresholds can be set and trended over time using the same approach described in the previous section. **See Figure 6** for the energy flow through the system and the sensor location used to collect VSWR data for the combined antenna path.

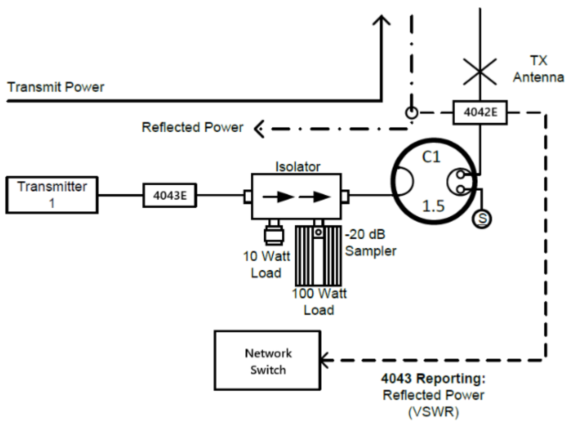

Figure 6: Composite VSWR measurement

One point to note regarding the 4042E sensor: the 4042E provides both **channelized** and **composite** measurements. It can report power on individual configured frequency channels, while also reporting the total (composite) power present on the combined line. As a result, while VSWR should remain relatively consistent under normal conditions, the forward and reflected **composite** power readings can vary significantly as different transmitters key on and off.

Because of this normal variability, it can be difficult to set a meaningful alarm based on composite forward power alone. However, the 4042E composite forward power reading can be very useful as a comparison point against the transmitter-specific 4043E readings, as outlined in the next section.

Combiner Performance - Cavity Tuning and Drift

Bird T-Pass cavity combiners are designed to combine multiple transmitter signals with low insertion loss and strong adjacent-channel isolation while maintaining effective transmitter noise suppression. T-Pass systems use multiple frequency-tuned, temperature-compensated cavity filters that are inherently low loss, power-capable, and mechanically stable over time. As a result, many T-Pass installations remain in service for decades.

In general, failures in T-Pass cavity combiners are uncommon. When issues do occur, they are most often associated with cavities that have been repeatedly retuned over time to accommodate site changes. In these cases, performance degradation is more likely to present as a tuning/response problem than a component that requires immediate replacement.

A typical challenge for a field technician during a service call is determining whether the combiner system is performing as expected—or whether an RF power issue is being caused elsewhere in the site. Ethernet sensors can be a valuable troubleshooting tool on site, and even more so when reviewed before traveling to a remote location. By comparing measurements from the 4042E and 4043E sensors, it is often possible to rule out the cavity combiner as the source of a suspected detuning or drift condition.

Problems with a T-Pass combiner can be identified by comparing the power measurement from a transmitter's associated 4043E sensor with the forward power reading from the 4042E sensor at the combiner output (antenna port). If the 4043E indicates the transmitter is producing the expected output power, but the 4042E shows lower-than-expected forward power at the antenna port, then there may be loss or attenuation in that transmitter's T-Pass combiner path.

To confirm this, key only the transmitter of interest and observe the corresponding channel power as measured by the 4042E at the combiner output. The observed per-channel loss can then be compared against previously recorded baseline data to determine whether combiner performance has changed. **See Figure 7** for an example of the transmit path and the measurement points used to characterize combiner performance.

One of the key benefits of the Ethernet sensors is remote web access to view these measurements in real time. A field technician can be off site while monitoring the sensor web interface, key individual channels using a handheld radio, and quickly determine whether the combiner is performing as expected based on the displayed power readings. This helps technicians arrive better prepared—with the right information and equipment—or avoid unnecessary site visits altogether.

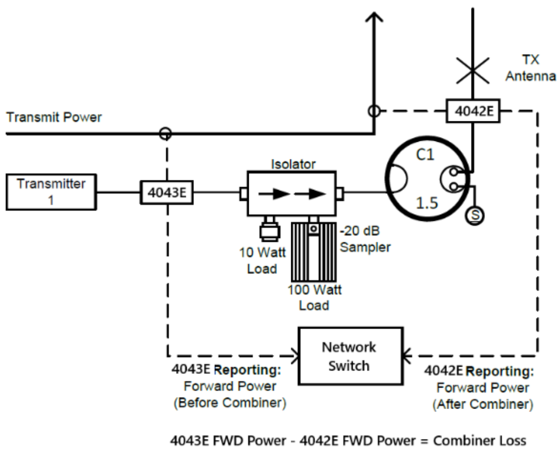

Figure 7: Combiner characterization through forward power characterization.

This comparison is performed by observing the dB difference between an individual transmitter's 4043E forward power reading (with no other channels active) and the corresponding 4042E channel power at the combiner output over time. A change in this loss—often associated with cavity detuning or drift—may be caused by temperature changes in the radio shelter or degradation of the cavity temperature-compensation mechanism.

Combiner Performance – Isolator Performance

While the cavities in a T-Pass combiners are inherently robust, the isolators that further protect transmitters can be more susceptible to failure. Under normal operation, an isolator provides additional transmitter-to-transmitter isolation, helping prevent RF energy from coupling between transmitter paths. It also limits the amount of reflected power that can feed back toward a transmitter, such as in the event of an antenna or transmission line fault.

If an isolator is exposed to power levels beyond its rating—whether from excessive reflected power or high transmitter power levels—it may overheat and fail.

Fortunately, isolator issues can often be detected through additional analysis of the sensor measurements. An isolator can fail in different ways depending on its construction. If an isolator fails in a way that behaves like a partially blocked or attenuated RF path—adding abnormal insertion loss in a given T-Pass leg—this condition can be detected using the same 4043E-to-4042E comparison technique described in the previous section.

However, in many cases an isolator may continue to pass RF energy in the forward direction but no longer provide the expected reverse-power isolation. In this condition, energy coupled back toward the isolator from the combiner path can leak toward the transmitter port instead of being routed to the isolator's termination as it is during normal operation.

This type of failure can be detected by comparing readings across adjacent transmitters' 4043E sensors. For example, if one transmitter is keyed and a second transmitter's 4043E sensor shows a noticeable rise in detected power—even though the second transmitter is not keyed—this may indicate reduced isolation due to a failed isolator on the second transmitter's T-Pass leg. This is because the cavity network alone may provide only limited TX-to-TX isolation (sometimes on the order of ~7 dB depending on frequency spacing), while the isolator typically provides the majority of the isolation (often ~50–60 dB). With an isolator degraded or failed, coupled energy may be only moderately attenuated and can still be detectable by the 4043E sensor.

See Figure 8 for an example of the transmit energy path through a failed isolator and the measurement points of interest.

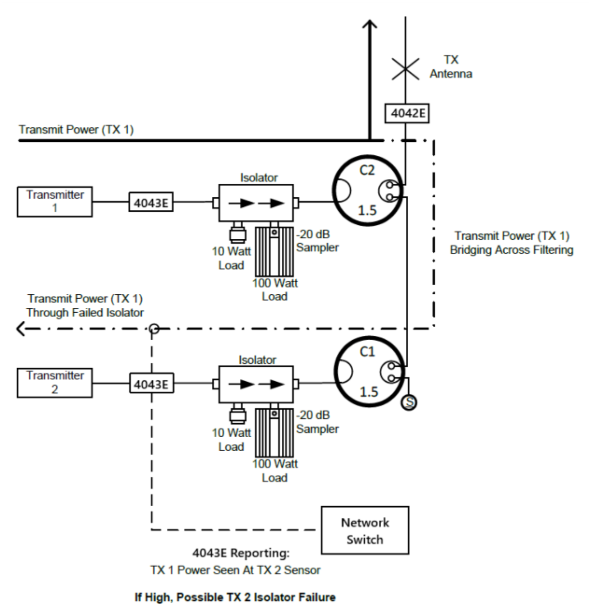

Figure 8: Isolator characterization through adjacent transmitter 4043E sensor data.

Conclusion – Practical Monitoring for Complex LMR Systems

Ethernet RF power sensors provide a practical, scalable approach to monitoring complex land mobile radio systems. By delivering continuous visibility into transmitter output, combiner performance, and antenna/feedline health, system managers gain the insight needed to detect issues early and respond more efficiently.

When deployed thoughtfully, these sensors reduce reliance on reactive troubleshooting, minimize unnecessary site visits, and support more confident maintenance decisions. As LMR systems continue to grow in size and complexity, remote monitoring becomes an essential complement to traditional on-site testing.

Need help applying this approach to your system?

Bird Applications Engineering can help evaluate sensor placement and monitoring strategies for your sites.

Request a Site Recommendation