APPLICATION NOTE

Reading Rotating Sensors

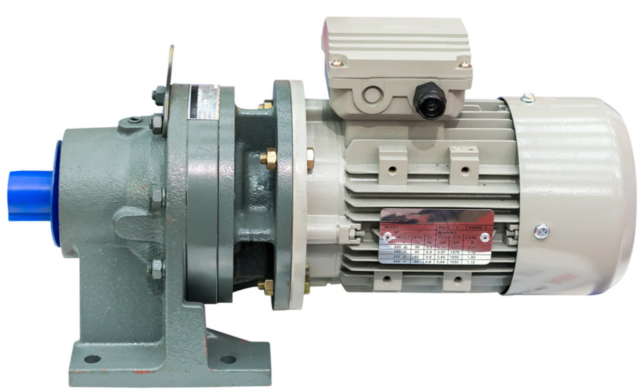
KEYWORDS
Sensor
Rotation
Axial sensor placement
Radial sensor placement
Angle of visibility
Read probability
Maximum rotation rate

ESSENTIAL POINTS
Axial or radial placement
Aligning the antenna
Orienting the antenna
RF reader settings
Probability of readings

Getting a handle on spinning surfaces

Wireless Smart Passive Sensing™ devices from Axzon are a good way to measure temperature on spinning surfaces. Wired systems require complex cable management strategies and even then, need robust cables that can handle many cycles of bending and twisting. Wireless sensors avoid all of this.

This application note discusses some of the best ways to use Axzon sensors to measure temperature on rotating surfaces and their limits.



Measuring rotating sensors

For the sake of discussion, this application note assumes a cylinder rotating vertically around its axis as shown below in Figure 1. It will review two sensor placements: sensor on top of the cylinder and sensor on the side of the cylinder. The concepts discussed, however, apply to other spinning shapes and in multiple orientations.

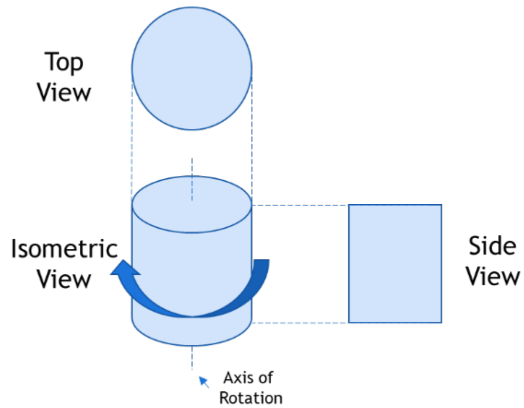
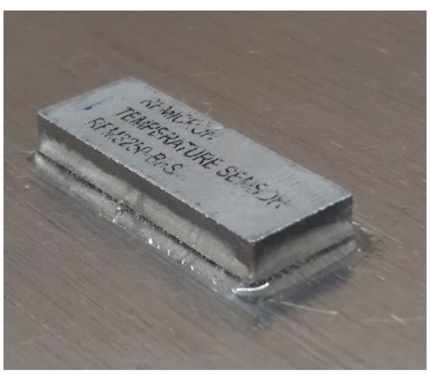


Figure 1: The rotating setup evaluated in this application note

Sensor on top of spinning cylinder

Here the sensor is mounted on top of the spinning cylinder as shown in Figure 2. For this configuration, it is best to place the antenna directly on top of the spinning cylinder. This way, sensor is always in view of the antenna.



RFM3250 sensor epoxied with clear Gorilla Epoxy around the edges.

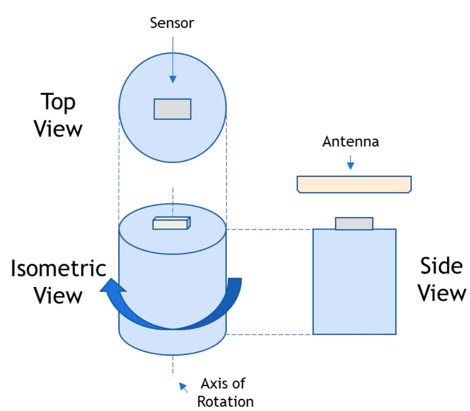


Figure 2: Sensor placed on the top of the rotating cylinder

It is also important to pay attention to the polarization of the antenna. Antennas can be either linearly polarized or circularly polarized. A linear antenna receives energy parallel to its polarization well but does not receive any energy perpendicular to its polarization. A circularly polarized antenna receives energy in all directions, but not as well as a properly aligned linearly polarized antenna.

In Figure 3, the purple arrows in the images show the direction of polarization. Axzon sensors are linearly polarized. If one uses a linearly polarized antenna, the rotating sensor will be aligned at some points (Figure 3a) but misaligned at other points (Figure 3b). A circularly polarized antenna is better in this case because the sensor can be read at any orientation (Figure 3c and Figure 3d). Since the sensor receives a good signal throughout the entire rotation cycle, it can be read successfully at very high rotation rates.

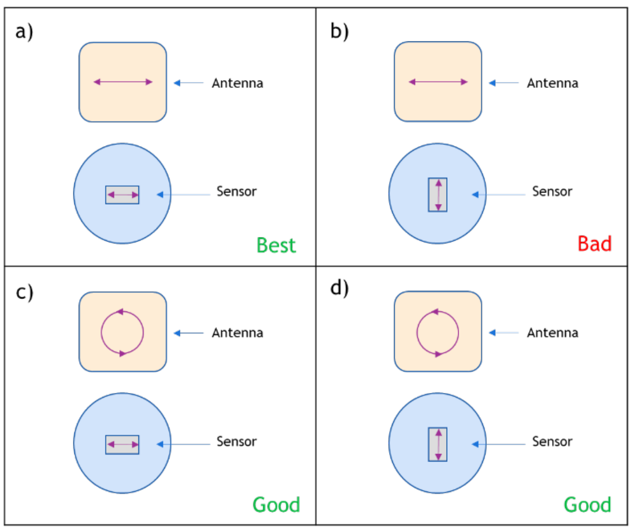


Figure 3: a) The linearly polarized antenna is aligned with the sensor's polarization, this results in the best signal. b) The linearly polarized antenna is perpendicular with the sensor's polarization. This results in a poor signal. c) and d) When using a circularly polarized antenna, sensor orientation does not matter. The signal is always good, but not as good as configuration (a).

Note that the analysis in this section is only true if the sensor remains in view of the antenna at all times. If a sensor is not visible for the full rotation cycle, there will likely be a rotation rate limit. Follow Section 2.2 for how to analyze a system in which the sensor is sometimes out of view. Some reasons why a sensor might not always be in view include: a piece of the mounting structure obscuring the sensor, or the sensor traveling in a wide arc that moves it far away from the antenna.

Sensor on side of spinning cylinder

Here the sensor is mounted on the side of the spinning cylinder as seen in Figure 4. For this configuration, it is best to place the antenna directly on the side of the spinning cylinder.

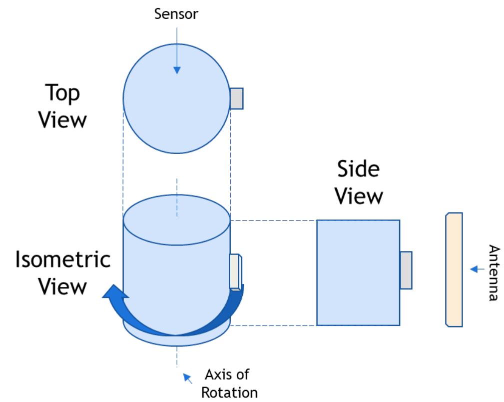


Figure 4: Sensor placed on the side of a rotating cylinder

Unfortunately, this means that the sensor drifts into and out of view. Figure 5 shows that the sensors can be read for only part of the rotation cycle. A 0° angle from the antenna is defined as the sensor directly facing the antenna. The sensor can still be read when the cylinder is rotated ±90°. When it is rotated beyond that, the sensor is behind the cylinder. In other words, the cylinder blocks RF energy from getting from the antenna to the sensor.

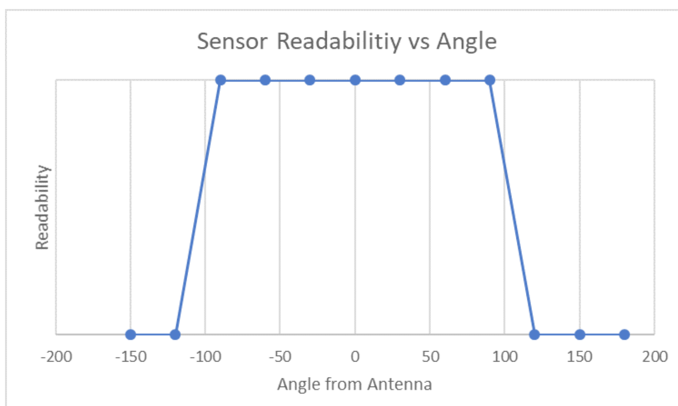


Figure 5: Readability of the sensor at different angles. Higher value is readable, lower value is not readable. 0° is pointing towards the antenna.

If the sensor loses RF energy while in the process of making a measurement, that reading will fail. In other words, the sensor must complete the measurement communications cycle while the sensor is at readable angles. A failed reading is shown in Figure 6 and a successful reading is shown in Figure 7.

Sensor Status	Hidden	Visible	Hidden
Read Attempt			Read Attempt

Figure 6: A failed read attempt

Sensor Status	Hidden	Visible	Hidden
Read Attempt		Read Attempt	

Figure 7: A successful read attempt

As rotation rate increases, the window when the sensor is visible decreases, making it harder and harder to complete a read attempt successfully. Eventually, the visible window is so short that it is impossible to make a successful read (Figure 8). The rotation rate when this occurs is the maximum rotation rate that can be read. The blue line in Figure 10 shows that the maximum rotation rate for successful reads using the RFM5104 handheld reader is approximately 700 RPM.

Sensor Status	Visible	Hidden	Visible	Hidden	Visible	Hidden
Read Attempt			Read Attempt			

Figure 8: Increasing rotation rate decreases the visible window. The read attempt does not fit in this smaller window.

Methods of increasing maximum read rate

There are two ways of increasing maximum read rate:

- Decrease the time it takes to complete a read.
- Increase the amount of time during which the sensor is visible.

Decrease the time it takes to attempt a read

Decreasing the time to complete a read allows the communication cycle to more easily it within a visible window. An example of this is shown in Figure 9. Two strategies for decreasing read time are increasing the data rate and by removing the CW tone during a temperature reading.

Sensor Status	Visible	Hidden	Visible	Hidden	Visible	Hidden
Read Attempt			Read Attempt			

Figure 9: A shorter read attempt is able to fit within a higher rotation rate's smaller visible window.

Increasing data rate allows bits to be transmitted more rapidly, allowing a read to finish faster. Some ways to do this are: reducing the Tari period, increasing BLF, and/or reducing symbol redundancy by switching to FM0 transmission mode from a Miller encoding [M2, M4, or M8].

As described in AN006, it is often useful to add a greater than 3ms CW tone after sending the select command that enables the temperature sensor. This provides a more stable reference for the temperature sensor, and results in more accurate reads. The 3ms, however, extends to the time it takes to read the temperature sensor and may push the end of the command out of the time window when the sensor is visible. Removing the CW tone allows for reading at higher rotation rates in exchange for less accurate temperature readings.

Figure 10 shows the relationship between read success rate and rotation rate. The orange and gray lines show increases in the maximum rotation rate by using faster data rates and removing the CW tone.
Different readers have different options for changing data rate. In addition, the effect of removing the CW tone is dependent on how much CW tone was there in the first place. Therefore, results will vary from reader to reader.

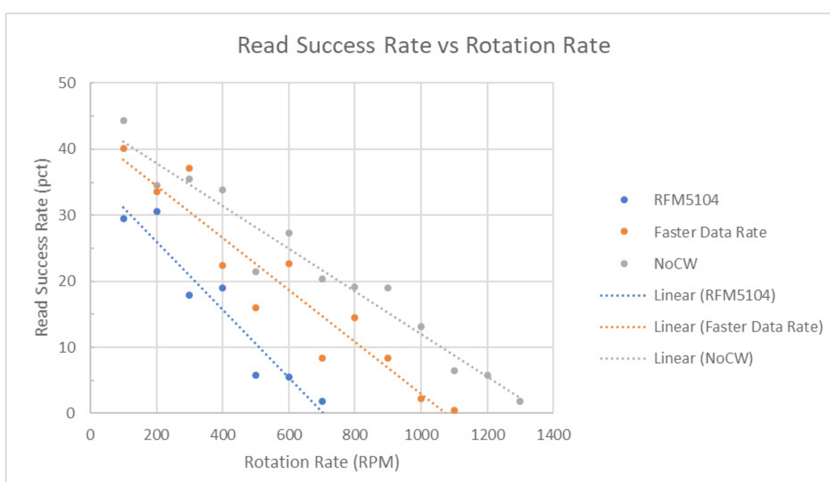


Figure 10: Read success rate decreases linearly with increasing rotation rate. Increasing data rate or removing the CW tone increases success rate and maximum rotation rate.

Likely, the more relevant metric is not what percentage of reads are successful, but how long it takes to get a successful read. The time for one successful read is shown for the same cases (using the RFM5104 handheld system, with increased data rate, and with no CW tone) are shown in Figure 11. Notice that the linear decrease in read percentage corresponds to an exponentially increasing time to read.

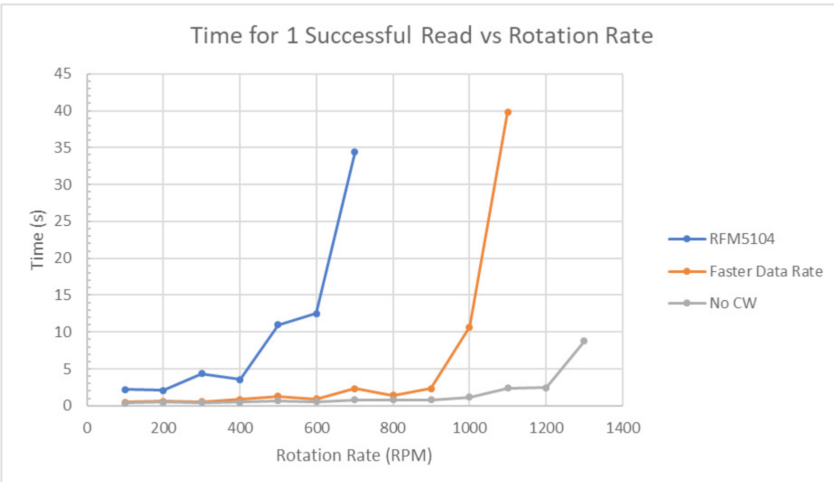


Figure 11: Time to complete a single successful read increases exponentially over rotation rate.

There are drawbacks for reducing read attempt time. Counterintuitively, using a faster data rate might make it take longer to read a stationary sensor. This is because, in general faster data rates are more susceptible to noise corrupting a packet. Removing the CW tone can reduce read range and increase noise in temperature measurements.

Increase the amount of time during which the sensor is visible

Another way to increase maximum rotation rate is increase the amount of time during which the sensor is visible (Figure 12). RF energy can bounce off of metal surfaces, so a properly placed surface on the opposite side of the spinning cylinder can reflect energy from the antenna to the sensor. This allows the sensor to be read from more angles, increasing the time available to read the sensor. This configuration is illustrated in Figure 13. This method, however, is very dependent on geometry. Some trial and error may be necessary.

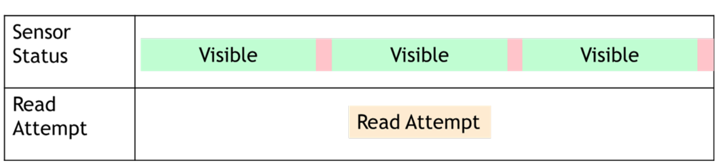


Figure 12: A read attempt is able to fit within the larger visible window, despite a faster rotation rate.

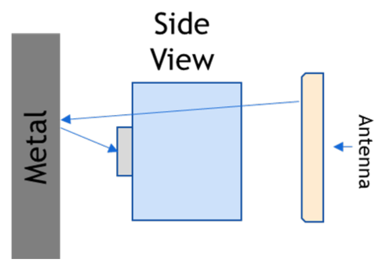


Figure 13: A metal sheet is used to reflect power from the antenna to the sensor.

Conclusions

Axzon's wireless Smart Passive Sensing technology is a good solution for measuring temperature on rotating objects.

Ideally the sensor spins in place instead of fading into and out of view. This is the case when the sensor is placed on top, circular face of the spinning cylinder discussed in this application note. A circularly polarized antenna will be able to read this sensor at very high rotation rates.

If the sensor has to fade into and out of view, as is the case when the sensor is placed on the side of the spinning cylinder, there is a maximum rotation rate. For the RFM5104 handheld system, the maximum rate is 700RPM. It may change for other reader/software combinations. The root cause of the maximum rate: the sensor needs to be visible the whole time a read is being attempted.

Sensor Location	Max rotation Rate	Antenna Placement	Antenna Polarization
On top	High	Top	Circular
On side	RFM5104: 700 RPM Others: Dependent on read attempt time	Side	Any

If one wishes to read tags spinning faster than this limit, one can either decrease read time, or increase the time over which the sen¬sor is visible in a rotation.