Circles of Success - A Brief Tutorial

By Randy Klassen, OMNEX Control Systems Inc.

OMNEX TRUSTED WIRELESS

With spread spectrum radios moving into the industrial workplace and out among the pipes and tanks, making the decision to install, specify or manufacture a wireless product is one that cannot be made lightly. No one likes to be embarrassed by product that doesn't work, and in the wireless arena where more and more products are now popping up new rules and guidelines have to be established to ease the decision-making process. This tutorial will focus on a few of the rules that will help HopLink distributors and end-users make decisions about specifying and installing wireless products successfully. It is designed to give you a simple tool for evaluating a HopLink installation's probability for success in terms of: a) where the HopLink will operate reliably, b) how much support you will have to give the product, and c) how to build trust in the eyes of your customer or manager by not "overselling" the HopLink's capabilities and achieving a quick and reliable installation.

To begin with, imagine three concentric circles, one inside the other, where the center circle is quite small, the next circle is about twice the diameter of the first, and the third is very large with a diameter approximately one hundred times that of the inner circle. These three circles will be called our "Circles of Success" and each circle will define a specific "zone" within which our rules will be developed.

As you'd expect, the crucial circle is the inner circle - the bull's eye. We will call this the No Worry Zone, and inside this circle is where a HopLink is considered "plug and play." Understanding the size of this zone and its characteristics will help you specify, sell and install a HopLink with nothing more than the 3 inch tall 1/4-wave omni antennas that come standard with the products.

The next circle out from the No Worry Zone is the Common Sense Zone, and here HopLinks can be installed successfully with appropriate antenna placement and perhaps only some minor installation adjustments. Often applications in this zone are first surveyed with distributor demo equipment - a very useful tool for people new to HopLink cordless wires who don't have the experience to "eyeball" an application. For applications in this zone, users are typically not dealing with engineering time, just the "tried it, modified things a bit, tried it again and bolted it down" method.

Finally, a HopLink in the center of these three circles sending its signal to a receiver in the large outer circle beyond the Common Sense Zone will require a propagation study in order for it to work. We call this the Performance Zone and this is not where most industrial users want to spend money getting a HopLink to work, and not where distributors want to be spending their time supporting an "over sold" application. This zone is best left to the "radio pros."

It's safe to say that traditionally radio has been used for moving serial data in and out of the Performance Zone. This stemmed from the fact that installing long run cable and conduit was too expensive for moving information around municipalities and large manufacturing facilities. Therefore, radios with high gain antennas placed atop towers were used and until recently, these types of applications, at these great distances, have defined the role of the industrial radio. But in recent years this has been changing, and industry is beginning to realize that wireless is a cost effective and reliable alter-native to cable in "short run" applications as well.

So it's probably safe to say that if industry can be shown that wireless is easy to use (without depending on propagation studies and engineered systems), easy to install, reliable and cost effective over distances typically found between sensors and control, there will be an explosion of wireless applications and products.

Unfortunately most radio manufacturers selling spread spectrum products into industry are their own worst enemies in the battle to win the trust of industrial users as they insist on advertising the maximum performance of their products touting range, range, range. Frankly, they should forget about selling "best-case scenario range" and just tell the user where he/she can expect the radio to work - without major engineering effort. And "telling it like it is" in the world of HopLinks is what we intend to do as we move you through some of the technical criteria that are used to define each circle. In doing so we hope to give you the information you need to better assess the HopLink applications you may be considering.

THE NO WORRY ZONE

For every transmitting radio, there exists a point in the distance where the receiver cannot pick up the signal from the transmitter. This point, where the signal is finally too weak to be successfully heard, is known as the receiver's "threshold." From this point, it logically follows that as the receiver is moved back towards the source of the transmission, the signal strength will rise above that

required to maintain an error-free link. Furthermore, as the receiver nears the transmitter, an area will be entered where the transmitter is putting out 1,000 times and even 1,000,000 times the amount of power needed for the receiver to have heard it at the "threshold" point ("radio people" will refer to these as areas with 30db margin and 60db margin, respectively). Here, amidst this enormous amount of signal strength, you end up in a zone where no amount of reasonable shielding (from walls, tanks, pipes, sheet metal, etc.), no amount of interference from other radios, nor any amount of EMI can disrupt the signal between transmitter and receiver. This is the region OMNEX calls the No Worry Zone, and it is here that a set of HopLinks are considered plug-and-play.

This zone is where end-users can easily install these devices in mere minutes and where distributors want to begin advertising the capabilities of the HopLink cordless wires, so that trust in their ability to perform can be established with each and every installation. Inside the No Worry Zone, performance essentially results from a grossly over-designed radio - the result being a product that just will not fail.

Now comes the question... in a harsh industrial environment filled with various types of interference, just how big is the No Worry Zone for different types of radios and how does one figure it out?

Let's begin by saying that more transmit power does not necessarily equate to a larger No Worry Zone. Radio "A" with 1 Watt of transmit power will not always have a bigger No Worry Zone than radio "B" with 1/2 Watt of transmit power. Why? It boils down to baud rate - something very few people consider when trying to determine the transmit distance of a radio. Baud rate impacts the size of the No Worry Zone in the following fashion. The number of obstructions a signal can power through, and/or bounce around on its way to its destination is directly proportional to the energy each bit is given by the transmitter. Knowing this allows us to formulate a simple "rule of thumb" equation for determining the size of the No Worry Zone. The formula is as follows:

$$\text{ENERGY PER BIT} = \frac{\text{TRANSMIT POWER}}{\text{BAUD RATE}}$$

People new to radio often assume that Transmit Power will be directly proportional to Energy per Bit, but this is not the case. Baud Rate has a dramatic effect on Energy per Bit: as Baud Rate increases, Energy per Bit decreases.

A good example would be to compare the No Worry Zones of a 1 Watt HopLink DX-900MA and a 1 Watt Ethernet LAN radio. The Energy per Bit for the DX-900MA will be 1/9600bps whereas the Energy per Bit for the Ethernet LAN radio could be 1/115000bps. Clearly, our formula isn't going to generate the No Worry Zone in feet and inches, but it does illustrate the fact that an Ethernet LAN radio devotes much less energy to each bit it sends, thus diminishing the size of its No Worry Zone.

In terms of typical spread spectrum radios on the market today, one can conclude that the proposed Bluetooth high speed, low power radio chips will have their No Worry Zone measured in tens of feet. High baud rate LAN PC to PC radios will have their No Worry Zones measured in hundreds of feet. And low baud rate I/O cordlesswires, such as the OMNEX HopLinks, will have their No Worry Zones measured in thousands of feet.

So what exactly are the dimensions of the No Worry Zone for a 1 Watt HopLink, like the unidirectional series using standard 1/4 wave omni antennas? Some common examples include:

- In-building, antenna on cabinet, heavily obstructed by walls and machinery = 600 feet
- In-plant, antenna outside, many steel structures obscuring line-of-sight = 1/4 mile

On another note, let's discuss receiver quality. The receiver's ability to discern whether an incoming bit is a zero or a one is completely dependent on how efficiently the receiver can overcome the "crackle" the radio itself generates. The cheaper the receiver, the less it can hear above its own noise level, so in a nutshell, cheaper receivers will have smaller plug-and-play zones. We often see this in the field with our HopLink TEX/REX series, where the 1/4 Watt TEX/REX radios maintain com-munications at greater distances than some competitors' 1 Watt high-speed radios. This is due to the fact that the REX-900 benefits from its own high quality receiver plus the very high Energy per Bit transmissions coming from the TEX-900 that is dedicating all it's signal strength to moving only a few analog and discrete signals.

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THE COMMON SENSE ZONE

If the No Worry Zone predicts indoor range under heavily obstructed conditions, the Common Sense Zone, beyond the bull's eye, predicts the range the end-user should expect to get out among the buildings of an industrial facility where obstacles are usually spread a little further apart. This is where customer imagination, simple technical support and the trying of a few thoughtful ideas come into play. In other words, this is where the wireless device gets the same attention as almost every other instrument being installed from day to day.

In a perfect wireless world, there would always be direct LOS. Nothing would stand between the transmitter and receiver and for a given amount of transmit power, every receiver could be pushed out to its threshold and maximum performance would be achieved. The radio world would be "one big No Worry Zone." But industrial applications rarely offer such pristine conditions and the receiver's threshold is often reached at some point less distant, as tanks, buildings and other obstacles typically block the path from the transmitter to the receiver.

With this in mind, let's assume for a moment that an installer has read the specs for a HopLink transmitter and knows that it is capable of sending its signal 4 - 5 miles LOS with a standard antenna. Now, let's also assumethat the transmitter he/she has to install in conjunction with a remote sensor needs to send its signal to a receiver beside a PLC approximately 1/2 mile away. You would probably agree that the 5 mile spec makes this 1/2 mile application sound easy, right? But, what if a tank farm obstructs the LOS signal? Is this application an immediate failure? Or can a bit of imagination and practical ex-perience get this installation on line? The installer has now entered the Common Sense Zone where he/she needs to think about and use some or all of the radio wave reflections possible in the industrial environment.

A good analogy for thinking about HopLinks in the Common Sense Zone is that of playing pool, a game where it is often necessary to "bank a shot" to get the cue ball to hit a desired target. And when a shot like this is to be made, the skilled pool player knows that a variety of factors affecting the outcome of the shot must first be taken into account. For example, the player knows that the cushion will absorb some of the energy he/she putsinto the shot, therefore reducing the distance the cue ball will travel. Similarly, the player realizes that since more energy is expended along a longer path of travel resulting from a "bank" or bounce shot, less energy will remain for the cue ball when it strikes the target. The player also knows that depending on how obstacles on the table are struck along the path, unwanted spin can occur, and that this has consequences as well. In the radio world, the same factors affecting energy lost to absorption, length of paths taken, and rotating polarity come into play in determining the size of the Common Sense Zone, and all play a part in reducing that 5 mile specified range to something quite a bit less.

What exactly does this mean for the installer then? Common sense should tell him/her to put his antennas outside and up high, where he/she can take advantage of all the helpful bounces, while at the same time "grabbing" the signals before their energy is absorbed by more layers of concrete and steel than necessary.Common sense will also tell him/her that omni antennas, sending and receiving signals in all directions, typically get better performance around the buildings,towers and tanks than Yagi directional antennas that basically have "one shot" at getting the signal through in a specific direction (sometimes the best bounce is achieved off a building 180 degrees opposite the intended target!). It will tell the end user that if his/her environment is very cluttered and the signal is bouncing a lot, he/she shouldn't expect much be-yond the 1/2 mile range, but that he/she just saved a ton of money by not laying cable and conduit.

Most often, a successful installation in the Common Sense Zone will boil down to thoughtfulness, patience and experience. In terms of the end-user, he/she should be aware that a little extra work might need to be applied to assure a solid, steady radio link. This is not to say that engineering time or plans and meetings are required, just a systematic approach to installation and an understanding that antenna placement, a few extra feet of cable and/or possibly a higher gain omni antenna may be needed to get the signal strength required for success.

In terms of the HopLink distributors, they will need to realize that some simple technical support may be needed for these applications and they should have someone trained to handle such calls. Likewise, it never hurts to have some of those peripheral items on hand so that the customer can get the extra equipment they need quickly (a good distributor will have asked the right questions about the application in advance and hopefully have had any extra equipment introduced and put on the customer's PO already).

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So, what are the "rule of thumb" transmit distances for the 1 Watt HopLink's Common Sense Zone? Think of this zone extending out 1/4 to 1/2 mile, depending on how close together the various obstructions are. If you've got your antennas outside and aligned to take advantage of all the possible bounces, you should be good to go without LOS.

THE PERFORMANCE ZONE

The Performance Zone is that area of the Circles of Success extending out from the Common Sense Zone to the point where a HopLink receiver's threshold is reached, given the upper limits of gain (6dB) allowed for a 1 Watt spread spectrum radio under the FCC. This is where the "radio experts" play and currently, a region where few of our many HopLink distributors have ventured. It typically ranges from 1/2 mile to 20+ miles for a 1 Watt HopLink, and opportunities to use the equipment out here usually arise from customer's needs to monitor and/or control distant wells, pumps, municipal lift stations, storage tanks, water/oil/chemical pipelines, etc. Whereas in-plant applications seldom encounter excessive shielding from trees and hills, Performance Zone applications are often affected by these and other similar obstructions that can severely attenuate the signal. To overcome these conditions and get the radio signals out where they need to be, poles or towers must be raised, repeater sites located, line losses calculated and antennas properly chosen. And usually this can't be accomplished with simple common sense. Therefore, those HopLink distributors who work in the Performance Zone use computer programs specifically designed to assess the viability of putting a HopLink into a long run application.

Two such programs that HopLink distributors are starting to use are:

http://www.pathloss.com/
http://www.micropath.com/

In a nutshell, here's what can be expected out of these 'pathloss' programs. Each program enables the user to enter the latitude and longitude of two sites, the type of radios being used, the output power of the radios, the types of antennas and the length of cables proposed, as well as a few other particulars. After following a series of fairly simple procedures, a path profile is then generated giving the user the transmission line losses, antenna centerline, clearance, fade margin, etc. In other words, you get a topographical set of 'pictures' of the application from which you can deduce whether or not the HopLink will work. By adding obstructions, changing antennas and varying antenna heights to the computer program's input, you can also see how various modifications to the installation could achieve the desired performance (if it failed onthe first attempt) or improve it if the signal strength is marginal. This is how the "radio experts" do it.

The key to the success of these programs is the accuracy of the data provided, coupled with the USGS terrain data that comes with the program. For example, Micropath comes with 90-meter terrain data for the entire USA or Canada, and other data for countries like Mexico can be purchased and/or downloaded from the web.

So are we recommending that all our distributors rush out and purchase one of these programs? No. Right now we figure that approximately 70+ percent of all HopLinks are being installed in the No Worry and Common Sense Zones, where elaborate pathloss calculations are not necessary, and if distributors are successful in these zones, they shouldn't change their plan of attack. But, as distributors have matured and expanded their HopLink business, we've noticed that the application envelope is being pushed out and the Performance Zone is being entered. As a distributor, if you're at this point now and wondering whether or not you should bid on projects beyond your scope of radio expertise, one option might be to explore the opportunity of offering pathloss studies as part of your business. Perhaps you can compete for that municipal job you thought only the "radio experts" owned.

The best advice we can give is to recommend that you to peruse the aforementioned websites to get a feel for what these programs can do for you. Then, based on how steep of a learning curve you feel must be overcome before being ready to support this type of service, you can make the decision if this is a direction you want to take your HopLink sales and if pathloss is a service you would like to offer.