By Jesse Yoder, Ph.D.

The Path to Chordal Harmony

Differentiating a 'chord' & a 'path' in ultrasonic flow measurement

Ultrasonic flowmeter transducers use piezoelectric crystals to generate an ultrasonic signal. When a voltage is applied to the piezoelectric crystals, an ultrasonic signal is created. The same piezoelectric crystals can also be used to detect the presence of an ultrasonic signal. In this way, an ultrasonic flowmeter transducer can be both a sender and a receiver of signals.

In flowmeter terminology, a path is defined as the route of travel between two ultrasonic transducers. The term "path" is critical in ultrasonic technology, because many ultrasonic flowmeters have been developed with multiple paths. Some ultrasonic meters have a single path, requiring one pair of transducers, and some have dual paths, requiring two transducer pairs. An important group of ultrasonic flowmeters has three or more paths; these meters are called multipath. Many of these multipath meters are used for custody-transfer applications.

Another term now in common use is the term "chord." Mathematically speaking, a chord is a straight line within a circle whose endpoints lie on the circumference. However, the term "chord" is also used by some ultrasonic manufacturers to refer to the route of travel between two transducers. In this way, a chord is like a path. However, a chord is considered to be the route of travel between a transducer and the pipe wall or reflector when the signal is bounced off a wall or a reflector. So in this sense, an ultrasonic signal that bounces off a wall or reflector to a receiving transducer has one path and two chords. One chord is the path of the signal from Transducer A to the pipe wall or reflector, and the second chord is the path of the signal from the pipe wall or reflector to transducer B.

This can be made clearer by distinguishing between a direct path and a reflected path. In a direct path, the signal goes from one transducer to another without being reflected. In a reflected or bounced path, the signal from one transducer is reflected or bounced off a reflector or the pipe wall on the way to the second transducer. Unlike a reflected path, a direct path is considered to have only one chord.

Why All This Matters

Why is it important to understand how paths and chords relate? The reason is that end-users perceive, rightly or wrongly, that the more paths or chords a flowmeter has, the more accurate it is and the more diagnostic information it is capable of gathering. Consequently, some suppliers have come to emphasize the number of chords their meter has over the number of paths, since this is often a higher number. In reality, the difference between chords and paths is far from obvious and requires some real studying to understand.

When I attended the CEESI Ultrasonic Meter Conference in June 2012 in Colorado Springs, I asked one of the speakers about this distinction. He replied that the term chord was "marketing speak." Then the moderator added that they are used to mean the same thing. Whether or not the term chord is marketing-speak, it is clear that "path" and "chord" do not mean the same thing.

In an effort to understand what all this means, I asked a number of suppliers to give their interpretation of paths and chords and what this difference means for ultrasonic flowmeters. Below are summaries of the responses from the representatives I spoke to.

KROHNE Inc.

[At KROHNE] we also speak of beams and chordal paths, which in "KROHNE-speak" refers to the "slice" of the flowstream they represent. A single chordal path (one path=two chords—one with flow, one against flow) is also spoken of as a single beam. This generally slices through the center of the pipe at its widest point. In KROHNE's world, we add more chordal paths or beams that do not cut through the center of the pipe so we can better deal with the flow profiles of the fluid and maintain accuracy throughout a broader operating range than possible in a single path/beam device. While it might not be directly represented in the accuracy specifications, more paths (more slices) result in better and consistent performance in a wider range of fluids or flowing conditions.

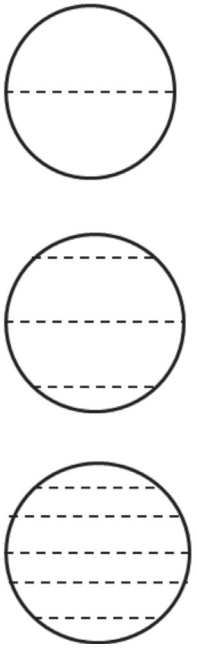

Figure 1. *Single-beam, three-beam, five-beam ultrasonic path configurations.*

Cameron Measurement Systems

Cameron provided the following definitions to help us understand the inner-working of ultrasonic flowmeters:

Transducer: Device for sending and receiving ultrasonic signals.

Path: Route of travel through the fluid between two transducers (Note: Both transducers on all paths ALWAYS play the role of both transmitter and receiver, i.e. a signal is sent along the path from A to B and then the roles are reversed and a signal is sent from B to A).

Diameter: Line joining two points on the circumference of a circle, passing through the center point.

Diametric path: Path that lines up on a diameter in a cross-sectional view of the meter.

Chord: Line joining two points on the circumference of a circle.

Chordal path: Path that lines up with a chord in a cross-sectional view of the meter.

Direct path: Path that connects

two transducers without using any reflection points. Direct paths can be diametric or chordal.

Reflected or bounce path: Path that connects two transducers via one or more reflection points. Reflected paths can be diametric or chordal (Note: Depending on where you wish the reflected path to go, the reflection point can either be the pipe wall itself, or a reflector can be used to send the path off at a different angle).

Traverse: Segment of a path connecting two points at the pipe wall—the points can either be defined by a transducer or a reflection point, and the traverse may be diametric or chordal.

Single bounce path: Path with one reflection point and two traverses.

Double bounce path: Path with two reflection points and three traverses.

Triple bounce path: Path with three reflection points and four traverses. *Comment: The above definitions seem fine, except that here "chord" has a purely mathematical definition. The definition of "traverse" seems close to what many manufacturers seem to mean by "chord." This is confirmed by a comment from Emerson, which indicates "a chord is the traverse across the ID of the pipe."*

Elster

A direct path is equal to a chord (or "chordal path"). A single reflection path consists of two chords and a double reflection path consists of three chords.

Taking a mid-radius double reflection path of Elster's Q.Sonic-Plus as example, it is three times longer compared to a direct mid-radius path (assuming the same angle). The fact that the travel time of the ultrasonic signal is longer, the time difference measured with and against the flow direction is also longer and results in a higher resolution and typically a better flow measurement accuracy and repeatability especially for the lower flows.

Also, the ultrasonic signal "collects" more gas velocity information when traveling longer and at different positions through the gas, which again may result in a more accurate flow measurement. To talk about chords instead of paths is simply to visualize this situation. In our case, a six-path Q.Sonic-plus has 16 chords.

Accusonic

Accusonic views the proper definition of a path in a fairly restrictive manner. Specifically, each path must incorporate its own independent "delta t" measurement. As such, an 18-path transit-time flowmeter comprises 18 paths with each path independently measuring delta t on

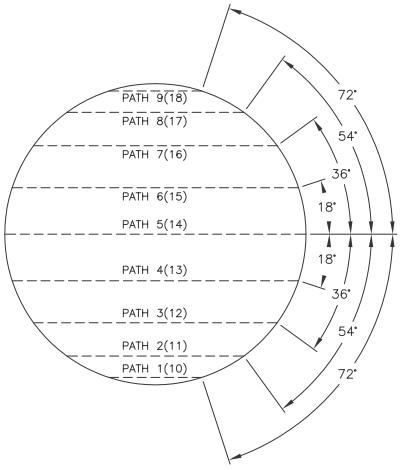

Figure 2. *18-path transit-time ultrasonic flowmeter with two planes of nine parallel paths.*

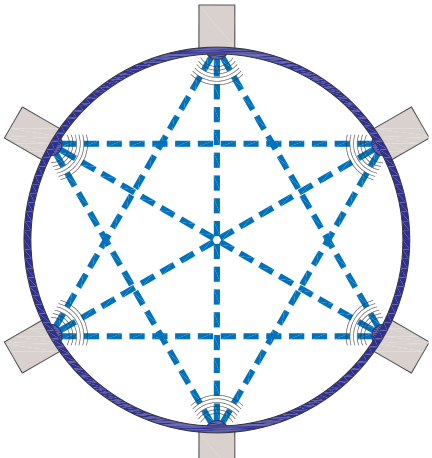

Figure 3. *18-path transit-time ultrasonic flowmeter with non-parallel paths.*

a continuous (repetitive) basis. Time of transit in the forward and reverse directions is measured along each path, and delta t is computed as the difference in these two measured times along each path. A path may be comprised of one or more chords, and both paths and chords may be parallel or non-parallel.

On the previous page are examples of two different types of 18-path transit-time flowmeters, one with two planes of nine parallel paths (symmetrically crossed) and one with 18 non-parallel paths (the end-view image shows half the total number of paths).

What It All Means

There appears to be pretty wide agreement among the manufacturers about the definitions of path and chord. A path requires two transducers, and it represents the path of an ultrasonic signal traveling back and forth between the two transducers. A chord represents the path of an ultrasonic signal going between two transducers. If the path is direct, then the transducers have one path and one chord going between them. If the path is reflected or bounced, then there is one path but two or more chords between the two transducers, depending on the number of reflections or bounces.

While the suppliers generally agree on definitions, they seem to have different views about the value of bounced or reflected paths. Some suppliers say that the added length of the chords in bounced or reflected paths provides additional diagnostic information and enhanced performance. It also can result in greater measurement accuracy and repeatability, according to some.

Other suppliers maintain that those who emphasize the number of chords over the number of paths are engaged in "marketing-speak" and that end-users may interpret the number of chords to be the same as the number of paths.

As is often the case in these types of debates, both sides have a point. The distinction between a path and a chord is somewhat involved and not so easy to understand. These types of definitions are not generally discussed in supplier literature, so end-users have to rely on journal articles or conference papers for this type of knowledge. Some end-users perhaps do not have the time or interest to follow the discussion in that much depth.

If having multiple chords in bounced paths really provides an edge in performance, accuracy, or flow profile analysis, then there is good reason to talk about the number of chords in an ultrasonic flowmeter. Perhaps this could be determined by an independent testing agency, such as Colorado Engineering Experiment Station Inc. (CEESI). It is not "marketing-speak" to talk about features that genuinely enhance performance, any more than it is "marketing-speak" to talk about ceramic bearings in turbine meters or sanitary linings in magnetic flowmeters.

On the other hand, suppliers who talk only about chords and don't mention paths might appear to be taking advantage of people's lack of knowledge about the terms. So one solution is to talk about the number of chords, but also talk about the number of paths at the same time. An example is Elster describes its Q.Sonic Plus as having six paths and 16 chords. This makes it clear how many chords are in the meter, but also makes it clear that there are actually fewer paths than chords.

Understand Well & Choose Wisely

In the final analysis, however, end-users also bear a responsibility to understand the terminology of the products they are buying. They should also use common sense in evaluating the claims of manufacturers. Of course manufacturers are likely to describe their products in the best light. Pressure transmitter suppliers have managed to get an entire generation to accept their designation of remotely programmable digital transmitters as "smart" since the term was introduced in 1983. While these transmitters are contrasted with analog transmitters, it is natural to think: "*If it isn't smart, it must be dumb.*" Somehow a highly emotive term has come to be treated like a purely descriptive one.

***Jesse Yoder, Ph.D.**, is president of Flow Research Inc. in Wakefield, Mass., a company he founded in 1998. Dr. Yoder specializes in flowmeters and pressure and temperature devices. Dr. Yoder can be reached at jesse@flowresearch.com.*

www.flowresearch.com

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