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MODULATION ERROR RATIO

By RON HRANAC

Awhile back I went target shooting with a friend. While at the range, it occurred to me that what is also known as plinking is a little like modulation error ratio (MER) used to characterize, say, the 64- and 256-QAM (quadrature amplitude modulation) digitally modulated signals we transmit to our customers. OK, before you start to wonder whether I've had too much coffee today, bear with me as I discuss this somewhat off-the-wall analogy.

Similarities

A typical target used at the range comprises a set of concentric circles printed on a piece of paper. The center of the target is called the bull's-eye, which carries the highest point value. The further away from the bull's-eye, the lower the assigned points. Ideally, one would always hit the bull's-eye and get the maximum possible score. In the real world, this seldom happens. Instead, one or two shots might hit at or near the bull's-eye, and most of the rest hit somewhere in the circles surrounding the center of the target. For a person who is a decent shot, plinking usually results in a fairly uniform "fuzzy cloud" of holes in and around the bull's-eye. The smaller the diameter of this cloud and the closer it is to the bull's-eye, the higher the score.

Factors affecting how close to the bull's-eye the shots land include the quality and accuracy of the firearm, type of ammunition used, weather conditions if outdoors, ambient lighting, and the distance to the target. But the biggest factor by far is the person doing the shooting: amount of plinking experience, squeezing vs. jerking the trigger, steadiness of aim, breathing control and so on. My targets' fuzzy clouds are definitely related to the person pulling the trigger. Those targets don't magically jump out of the way when I shoot, although I'd swear that's what happens sometimes. But I digress …

Now visualize the constellation display on a QAM analyzer. Each symbol landing on the constellation can be thought of as a target of sorts. For instance, a 64-QAM constellation has 64 targets arranged in an eight-by-eight square-shaped grid. Ideally, when the 64 symbols are transmitted, they should land exactly on their respective targets' "bull's-eyes." In reality, the symbols form a fuzzy cloud at and around the constellation's target centers. When we measure MER, we are in effect measuring the fuzziness of those clouds. The smaller the fuzzy clouds, the higher the MER. Like a high score in target shooting, the higher the MER, the better.

What MER is ... and isn't

All right, high MER is good, and low MER is not. Just what the heck is MER, anyway?

Modulation error ratio is the ratio, in decibels, of average symbol power to average error power: MER(dB) = 10log(average symbol power/average error power). From this, you can see that the fuzzier the symbol cloud—that is, the greater the average error power—the lower the MER. Mathematically, a more precise definition of MER is:

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where I and Q are the real (in-phase) and imaginary (quadrature) parts of each sampled ideal target symbol vector, and δI and δQ are the real (in-phase) and imaginary (quadrature) parts of each modulation error vector. This definition assumes that a long enough sample is taken so that all the constellation symbols are equally likely to occur.

MER is affected by pretty much everything in a digitally modulated signal's transmission path: transmitted phase noise; carrier-to-noise ratio (CNR); nonlinear distortions (composite triple beat, CTB; composite second order, CSO; cross modulation, X-mod; common path distortion, CPD); linear distortions (micro-reflections, amplitude tilt/ripple, group delay); in-channel ingress; laser clipping; data collisions; and even suboptimal modulation profiles. Some of these can be controlled fairly well, but no matter what we do, a digitally modulated signal is going to be impaired as it makes its way through a cable network. The worse these impairments, the fuzzier the constellation landings. The fuzzier the constellation landings, the lower the MER.

As such, the constellation's symbol landings will never be perfectly small points. They will always be spread out at least a little, the extent of which is described by MER. By itself, the measured MER value doesn't tell us what caused it to be low in the first place, only that it is low. Crummy CNR? Beats? Group delay? Hard to say, until you do some additional diagnostics with your trusty QAM analyzer. For more on this, see "Digital Troubleshooting, Part 1" and "Troubleshooting Digitally Modulated Signals, Part 2" in the June and July 2006 issues of Communications Technology.

Confusion

I've written on a number of occasions about the confusion that exists regarding MER and CNR. They are not the same thing. Adding to the confusion is the fact that MER is often called signal-to-noise ratio, or SNR. A good example is a cable modem termination system's (CMTS's) reported upstream SNR. That parameter is MER, not CNR. Likewise, most set-tops and cable modems can report an SNR value, but here, too, it's MER—downstream MER, that is.

Not confused enough yet? MER can be an equalized value or an unequalized value. Both are legitimate parameters, but they are different. Equalized MER is the value after the QAM receiver's adaptive equalizer compensates for some or most of the in-channel complex frequency response impairments. Unequalized MER is the value before the QAM receiver's adaptive equalizer does its magic. This means that for the same signal under identical conditions, unequalized MER will always be at least a few decibels less than an equalized value. So if you replace a CMTS (or line card) that reports equalized upstream MER with one that reports unequalized MER, you'll find that your upstream "SNR" (MER) is likely a few decibels less than before. This is normal. And no, you can't simply add a correction factor to the unequalized MER number to get an equivalent equalized MER. It doesn't work that way.

Most QAM analyzers report equalized MER, as do set-tops and cable modems. Some CMTSs report equalized upstream MER; some report unequalized upstream MER. Some test equipment supports measurement of both equalized and unequalized MER—downstream and upstream. My personal preference is unequalized MER, since a low value may indicate the presence of linear distortions if the CNR checks out OK.

More

If you're interested in a deep dive into the subjects of CNR, SNR and MER, I suggest you take a look at the white paper that Broadcom's Bruce Currivan and I recently co-authored. It's 41 pages long, includes some gnarly math, and treats the subject matter in-depth—you might want to get a strong cup of coffee when you read it. You'll find "Digital Transmission: Carrier-to-Noise Ratio, Signal-to-Noise Ratio, and Modulation Error Ratio" online at the following URLs:
www.cisco.com/en/US/products/hw/cable/ps2209/products_white_paper0900aecd805738f5.shtml
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