Using Quality Tools for Troubleshooting a Satellite Communications Link

The purpose of this paper is to describe how a Fishbone Diagram can be used to identify problems with satellite link performance such as loss of lock or high bit error rate (BER). This represents a relatively new application of an old and familiar tool which is used elsewhere in the satellite industry.

Why is this needed? One reason is that interference has never been more prevalent in satellite links. For example, at Ku band, interference from radar detectors in vehicles is influencing the selection of antenna sites, requiring expensive shielding and causing other problems. This is probably the subject of a future column in this publication, but suffice it to say that TI (terrestrial interference) at Ku Band is a new fact of life. At C Band, terrestrial interference continues to be a problem, with military and aviation electronics frequently the source of the problem, and the extensive introduction of "extended band" LNBs a contributory factor.

Moreover, satellite interference, from the same or an adjacent satellite, continues to be a problem as more and more links are converting to digital and both analog interference and saturated transponder digital interference cause problems to smaller and smaller antennas. Interference has become such a major problem that the Satellite Users Interference Reduction Group, (SUIRG), an industry association formed in 1993, recently incorporated to allow it to be more pro-active and focus its efforts of combating interference before it begins.

To the layman or even the engineer without extensive satellite operational experience, sorting out the causes of poor link performance can be difficult when there are so many possible factors, such as (in no particular order):

- Link or equipment design not robust enough for normal levels of interference
- Interference from the same satellite being used
- Interference within the uplink itself
- Terrestrial Interference
- Personnel errors/ lack of operator training

- Adjacent Satellite Interference

Each of these factors contains several sub-factors, any one of which could cause poor satellite link performance. Working through this myriad of possible causes for a poorly performing satellite link can be daunting to all but the highly experienced professional.

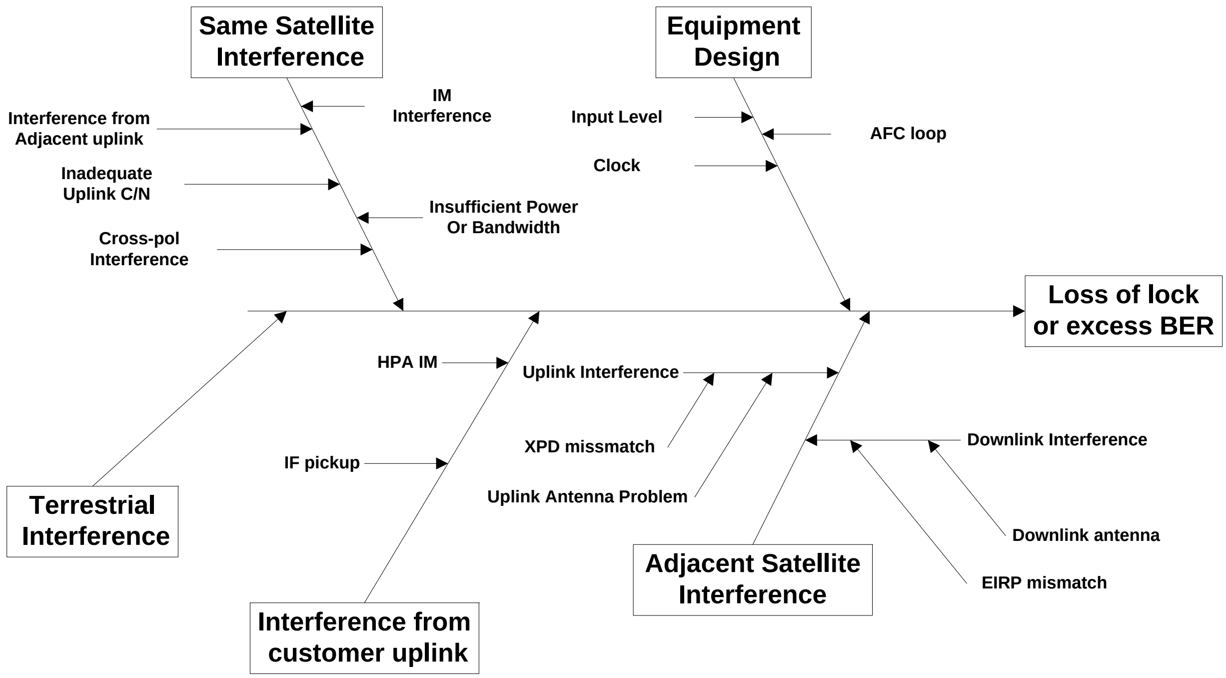
How a Fishbone Diagram Can Help

How can a fishbone diagram help? To begin with, let’s review some facts about fishbone diagrams. They were invented in 1943 by Kaoru Ishikawa, who pioneered quality management in the Kawasaki shipyards, and they are sometimes called "Ishikawa Diagrams". (They are also called "Cause and Effect Diagrams" and the template for constructing them is in Visio software, as well as existing for Microsoft Word and Excel.)

More importantly, these diagrams have been effectively used by spacecraft engineers for many years! Whenever a satellite failure occurs, you can expect that an engineer somewhere is putting together a fishbone diagram to try to learn what caused the problem.

The value of the fishbone diagram is to assist in categorizing the many potential causes of a problem in an orderly way and in identifying root causes. It provides a comprehensive view of all the causes of a particular outcome, in this case poor digital link performance.

An example of a fishbone diagram used to diagnose a satellite link problem is shown in the figure below.



In a fishbone diagram, from a single outcome or trunk (in this case, loss of lock or excess BER), branches extend that represent major categories of possible causes of that single outcome. These large branches then lead to smaller and smaller branches of causes all the way down to twigs at the ends. Any single twig could be the source of the problem. For example, in the diagram above, excess BER could be caused in a direct or contributory manner by Adjacent Satellite Interference (the trunk), namely Downlink Interference (the branch) and, in particular, Downlink Antenna Problems (such as bad sidelobes), the twig.

Process for Using the Fishbone

The general process for using the fishbone is described below. The above diagram contains most factors which could cause poor digital satellite link performance, but each individual link has different particulars such as adjacent satellites, equipment details, etc:

1. Confirm and determine applicability of the broad categories (trunks) and the factors within each category (branches) that may be causing the poor link

performance. Repeat this procedure with each factor under the category to validate or produce new sub-factors (twigs). Continue asking, "How could this happen?" and put additional factors and subfactors as applicable to the specific link situation. For example, "operator error" may be a category in some situations and a trunk would be appropriately added.

2. Continue until you no longer get useful information as you ask, "What other factors could be causing poor performance?"

3. After drawing the diagram, color the branches and twigs using three colors to apply existing link analysis data, test and measurement data (such as an on-site RFI survey, downlink spectrum analyzer plots, experiment (lab) results, etc):

   a. Green- known not to be a problem

   b. Red – definitely a contributing factor but unknown as to degree of causality (is it the only cause or just a contributing cause)

   c. Orange- unknown as to whether it contributes to the problem

4. Identify the need for additional analysis, tests or measurements, or lab work in some cases, to determine if the "orange" factors above are contributory, and the degree to which the "red" factors are responsible for the problem.

5. Conduct the additional analyses and tests and redraw the diagram with results, until the causes (red branches) are clearly identified and their relative causality is understood.

Advantages of a Fishbone

The advantages of using a fishbone diagram are several. For one, it permits a rigorous analysis which overlooks no possible problem source (that’s why it is used when satellites fail). Without it, the approach might be "hit or miss" depending upon individual expertise. Also, it fosters "brainstorming" among several troubleshooting team members such as operators, engineers, and satellite operators, and gives each the "big picture" as to possible causes or influencing factors. By recursively re-coloring the diagram, it provides clear indication of areas where further investigation resolution (test) efforts are needed and should be focused. Even after the problem is resolved, it shows areas of weakness in the link design which could be rectified in the future.

The fishbone diagram in this manner can be quite valuable in organizing thoughts and following a logical, sequential approach to troubleshooting link problems. This method is economical of time and can be pursued without "going over the same ground over and over again".

The fish bone or Ishikawa diagram is just one of the tools used in the Quality Sciences that are available to be used in the satellite communications industry. There are many others like the Pareto diagrams, FME analysis, SIPOC, Five Whys, Control Charts and SPC just to mention a few that can be used when running a satcom network. These tools are extremely useful to find root causes of problems, analyze trends and staying focus on the customer needs.

Current networks can record data that is very useful for analyzing the behavior of the network and use patterns. But just the data is not enough, there needs to be the means and personnel that in a disciplined, systemic and educated way can interpret the data that an NMS is providing. Tools like Six Sigma and TQM are not just manufacturing floor tools anymore, they are extremely useful when maintaining a telecommunications network.