



Monitoring of International Space Station Telemetry Using Shewhart Control Charts

This technique can be applied to monitoring critical systems such as electrical power generation and manufacturing equipment.

Lyndon B. Johnson Space Center, Houston, Texas

Shewhart control charts have been established as an expedient method for analyzing dynamic, trending data in order to identify anomalous subsystem performance as soon as such performance would exceed a statistically established baseline. Additionally, this leading indicator tool integrates a selection methodology that reduces false positive indications, optimizes true leading indicator events, minimizes computer processor unit duty cycles, and addresses human factor concerns (i.e., the potential for flight-controller data overload). This innovation leverages statistical process control, and provides a relatively simple way to allow flight controllers to focus their attention on

subtle system changes that could lead to dramatic off-nominal system performance. Finally, this capability improves response time to potential hardware damage and/or crew injury, thereby improving space flight safety.

Shewhart control charts require normalized data. However, the telemetry from the ISS Early External Thermal Control System (EETCS) was not normally distributed. A method for normalizing the data was implemented, as was a means of selecting data windows, the number of standard deviations (Sigma Level), the number of consecutive points out of limits (Sequence), and direction (increasing or decreasing trend data). By varying these options, and

treating them like dial settings, the number of nuisance alerts and leading indicators were optimized. The goal was to capture all leading indicators while minimizing the number of nuisances. Lean Six Sigma (L6S) design of experiment methodologies were employed. To optimize the results, Perl programming language was used to automate the massive amounts of telemetry data, control chart plots, and the data analysis.

This work was done by Jeffery T. Fitch, Alan L. Simon, John A. Gouveia, Andrew M. Hillin, and Steve A. Hernandez of United Space Alliance for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24530-1

Theory of a Traveling Wave Feed for a Planar Slot Array Antenna

A design procedure was developed for the coupling slots between the feed waveguide and the radiating waveguides.

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Planar arrays of waveguide-fed slots have been employed in many radar and remote sensing applications. Such arrays are designed in the standing wave configuration because of high efficiency. Traveling wave arrays can produce greater bandwidth at the expense of efficiency due to power loss in the load or loads. Traveling wave planar slot arrays may be designed with a long feed waveguide consisting of centered-inclined coupling slots. The feed waveguide is terminated in a matched load, and the element spacing in the feed waveguide is chosen to produce a beam squinted from the broadside.

The traveling wave planar slot array consists of a long feed waveguide containing resonant-centered inclined coupling slots in the broad wall, cou-

pling power into an array of stacked radiating waveguides orthogonal to it. The radiating waveguides consist of longitudinal offset radiating slots in a standing wave configuration. For the traveling wave feed of a planar slot array, one has to design the tilt angle and length of each coupling slot such that the amplitude and phase of excitation of each radiating waveguide are close to the desired values. The coupling slot spacing is chosen for an appropriate beam squint. Scattering matrix parameters of resonant coupling slots are used in the design process to produce appropriate excitations of radiating waveguides with constraints placed only on amplitudes.

Since the radiating slots in each radiating waveguide are designed to pro-

duce a certain total admittance, the scattering (S) matrix of each coupling slot is reduced to a 2×2 matrix. Elements of each 2×2 S-matrix and the amount of coupling into the corresponding radiating waveguide are expressed in terms of the element S_{11} . S matrices are converted into transmission (T) matrices, and the T matrices are multiplied to cascade the coupling slots and waveguide sections, starting from the load end and proceeding towards the source.

While the use of non-resonant coupling slots may provide an additional degree of freedom in the design, resonant coupling slots simplify the design process. The amplitude of the wave going to the load is set at unity. The S_{11} parameter, r' of the coupling slot closest to the load, is assigned an arbitrary

value. A larger value of r' will reduce the power dissipated in the load while increasing the reflection coefficient at the input port. It is now possible to obtain the excitation of the radiating waveguide closest to the load and the coefficients of the wave incident and reflected at the input port of this coupling slot. The next coupling slot parameter, r' , is chosen to realize the excitation of that radiating waveguide. One continues this process moving towards the source, until all the coupling slot parameters r' and hence the S_{11} parameter of the 4-port coupler, r , are known for each coupling slot. The goal

is to produce the desired array aperture distribution in the feed direction. From an interpolation of the computed moment method data for the slot parameters, all the coupling slot tilt angles and lengths are obtained. From the excitations of the radiating waveguides computed from the coupling values, radiating slot parameters may be obtained so as to attain the desired total normalized slot admittances. This process yields the radiating slot parameters, offsets, and lengths. The design is repeated by choosing different values of r' for the last coupling slot until the percentage of power dissipated in the

load and the input reflection coefficient values are satisfactory.

Numerical results computed for the radiation pattern, the tilt angles and lengths of coupling slots, and excitation phases of the radiating waveguides, are presented for an array with uniform amplitude excitation. The design process has been validated using computer simulations. This design procedure is valid for non-uniform amplitude excitations as well.

This work was done by Sembiam Rengarajan of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48221

Time Manager Software for a Flight Processor

John F. Kennedy Space Center, Florida

Data analysis is a process of inspecting, cleaning, transforming, and modeling data to highlight useful information and suggest conclusions. Accurate timestamps and a timeline of vehicle events are needed to analyze flight data. When data is gathered onboard a rocket, precise time stamping is even more important due to the rocket's high speeds and the requirement to integrate data over time for inertial navigation calculations.

Accurately time-tagging data currently requires an additional accurate timecode generator board. This solution is costly but is usually adequate for ground-based systems. However, this solution is not adequate for flight processors on rockets. Rocket systems require more costly ruggedized equipment where weight, size, and power constraints are an issue. Redundancy is also required, adding even more to the sys-

tem's weight, size, and power consumption.

By moving the timekeeping to the flight processor, there is no longer a need for a redundant time source. If each flight processor is initially synchronized to GPS, they can freewheel and maintain a fairly accurate time throughout the flight with no additional GPS time messages received. However, additional GPS time messages will ensure an even greater accuracy.

Some modern microprocessors maintain a 64-bit internal time-base register that is incremented by a crystal oscillator, usually with a 20- to 100-MHz frequency. This time-base register can be read in an interrupt service routine (ISR) generated by the 1 pps signal from the GPS receiver. Next, a GPS time message is received. The time-base count is associated with the GPS time message time.

When a timestamp is required, a get-time function is called that immediately reads the time-base register. A delta count is calculated from the last GPS sync. The current time is calculated by adding this delta time to the last sync time. This process calculates a timestamp with an accuracy measured in microseconds, depending on the processor clock speed and the accuracy of the processor clock. If a 1 pps GPS ISR is not available, the time base register can be synchronized with the receipt of the GPS time message. If the microprocessor does not have a 64-bit internal time-base register, a count-down timer can be used.

This work was done by Roger Zoerner of ASRC Aerospace Corporation for Kennedy Space Center. For more information, contact the Kennedy Space Center Innovative Partnerships Office at 321-867-5033. KSC-13406

Simulation of Oxygen Disintegration and Mixing With Hydrogen or Helium at Supercritical Pressure

These models can be used in simulations of gas turbine engines.

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The simulation of high-pressure turbulent flows, where the pressure, p , is larger than the critical value, p_c , for the species under consideration, is relevant to a wide array of propulsion systems, e.g. gas turbine, diesel, and liquid rocket

engines. Most turbulence models, however, have been developed for atmospheric- p turbulent flows. The difference between atmospheric- p and supercritical- p turbulence is that, in the former situation, the coupling between dynamics

and thermodynamics is moderate to negligible, but for the latter it is very significant, and can dominate the flow characteristics. The reason for this stems from the mathematical form of the equation of state (EOS), which is the