REQUIREMENT FOR A DATA QUALITY ASSURANCE PROGRAM

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Summary The requirement for a Data Quality Assurance Program for telemetry ground station operations is outlined. Examples are given for frequency division and time division formats to demonstrate that a practical and meaningful program is within the state-of-the-art and in fact that the basic modules have already been developed for commercial communication systems. A program is recommended for expansion of the IRIG Standards to include performance criteria and specifications of end-to-end ground station tests for determining that the criteria are satisfied for each mission.

Introduction The IRIG 106-66 Standards imply the use of a much greater base bandwidth for frequency division systems. In the constant bandwidth FM/FM, operation of greater numbers of channels at lower deviation ratios requires lower cross-talk and noise levels than before. Also, the transition to UHF involves lower RF power generation efficiency, greater antenna directivity for the same aperture and larger receiver noise figures if conventional RF amplifiers are used. Larger gain transmitting antennas, which involves pointing, and/or greater efficiency in the use of RF power to offset these losses are required. These considerations all require that the user be informed as to what performance he can expect from range supplied and operated equipment in order that he may design a telemetry system to meet the needs of his mission.

Relative to frequency division, existing IRIG Standards state what amounts to the bandwidth of subcarrier channel filters and discriminators and the bandwidth of low-pass channel output filters. The frequency standards state the allowable spectrum occupancy. This leaves the setting of subcarrier and carrier deviations to the user. The section on tape recorders specifies head configurations, tape speeds, bandwidths, etc., but sets no standards on intermodulation, flutter, noise, etc. (This section does describe test methods.) Thus, there is no statement of the maximum allowed noise and distortion in the ground equipment under defined conditions. In other words, as it now stands, the user has no reliable knowledge of the performance of the range supplied and operated equipment. What is needed is a statement of minimum allowable overall performance criteria plus specification of end-to-end tests which are designed to show that these criteria are met and that the equipment is ready for a particular mission.

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The same observation can be made relative to time division systems. Receiver IF bandwidth, synchronization and data format are given but no performance criteria for receivers, tape recorders, synchronizers and detectors are given. In time division, the two principal error sources are noise, both thermal and impulse, tape jitter and pulse shape distortion. In PAM and PDM, the latter causes analogue type cross-talk and in PCM, it increases the bit error probability.

What is needed amounts to a range DATA QUALITY ASSURANCE PROGRAM in which overall criteria are established and end-to-end tests defined to determine performance of range supplied and operated equipment and to assure that the criteria are met. In analyzing the problem, two types of missions must be recognized. Type one involves recording only and the other type involves real-time and/or quick look data. In type one, it is only necessary to establish a test from antenna input to recorder output. In type two, the tests must be from antenna input to data channel output. In the latter case, it must be recognized that the precision required for realtime use may be as great as that required for post-time data.

Frequency Division

Type one mission The two sources of error to be tested here are additive noise, including environmental, and distortion leading to cross-talk. Of course, the effects of both of these sources can be evaluated by a complete simulation as in the EMR report, but for type one missions, this is unnecessary. The notch noise test is an adequate simulation for this purpose. This test and standard equipment were developed for subcarrier microwave relay stations. Fig. 1 is a block diagram illustrating this method.

The spectrum shaper approximates the subcarrier taper and cuts off at the maximum base band frequency to be used. The notches are distributed across the base band. It is necessary that the notches occupy only a small portion of the base band so as not to interfere with the loading of the radio link. The attenuator is set to provide the depth of carrier modulation consistent with the frequency standards and/or the receiver IF to be used. The band pass filters are centered at the notch frequencies and are narrower than the notches. Thus with the notch filters in, only additive noise and cross-talk noise is passed by the band pass filters. Consider the output power P of a single band pass filter. Let

P_1 = output power with notch filter out with large RF signal = channel signal power plus residual noise power.

P_2 = power output with notch filter in with large RF signal residual noise power (including intermodulation).

P_3 = power output with notch filter in at low and intermediate carrier S/N = residual noise power plus added RF noise power.

P_4 = power out with no input modulation to signal generator with large RF signal ≅ residual noise power (excluding intermodulation).

P_5 = power out with no input modulation to signal generator at low and intermediate carrier S/N = residual noise power plus added RF noise power.

Then:

$\frac{P_1 - P_2}{P_2}$ = ultimate output signal-to-noise ratio for large carrier S/N.

$\frac{P_1 - P_2}{P_3}$ = output signal-to-noise power at low and intermediate carrier SIN. This includes residual and added RF noise.

$\frac{P_1 - P_2}{P_4}$ = ultimate output signal-to-noise ratio for large carrier SIN not including intermodulation. This assumes that the residual noise (not including intermodulation) is independent of modulation.

$\frac{P_1 - P_4}{P_5}$ = signal-to-noise power ratio at low and intermediate carrier SIN. This includes residual noise and added RF noise but not intermodulation noise. This assumes that the residual and added RF noise are independent of modulation. This is not a bad assumption for our purpose.

In the above, it is assumed that the signal power level of the receiver output is independent of the input signal power level. This is a good approximation over the carrier S/N range contemplated. If a correction is desired, it is only necessary to measure each power quantity involved at the selected carrier S/N.

The above relations give the subcarrier channel S/N to a good approximation and can be used to predict data channel output S/N by means of experimental data (as from EMR report Table I-3.5-8, for example) or by theory. For type one missions, the tape recorder should be included. Also if radio or other type relay of the signal is made, the test should be made with the relay in.

For example, the Marconi 0A2090 test set is available commercially and notch and band pass filters are available which are approximate for the above measurements. In final equipment versions, the tests should be automated to provide go-no go indication, in accordance with criteria established in reference to the mission, plus a permanent record of the test data.

Type two mission If the telemeter is to be used in real time for closed loop operation, it appears that some form of complete end-to-end test is required. This test must be designed to be consistent with mission requirements and, depending on the mission, a more or less complete baseband simulation is required in which a quantitative comparison is made between data input and data output channels in order to determine that the ground station is properly interconnected and to evaluate the signal-tonoise ratio in individual output data channels. This can involve considerable amounts of equipment when time delay in the system, statistically meaningful sampling, etc., are taken into account. For quick look data, it appears that routine maintenance testing of the baseband processing equipment is satisfactory since precision data are generally not required for quick look. Then too, it is possible to refine quick look data if the tape recordings are of good quality, i.e., if the type one mission is adequately performed.

Time Division

Type one mission If the time division signal is on a subcarrier which is part of a frequency division multiplex, then it may be assumed that the notch noise test is adequate for type one mission. If the time division base band signal directly modulates the carrier, then the notch noise test is not adequate since it does not give a complete picture of the transient response of the radio link, tape recorder, etc. At this point, only PCM will be discussed because direct PAM and PDM are much less frequently used. (Adequate tests for these systems are practical.)

In PCM the important quantity is bit error probability versus received carrier strength. Test equipment has been designed and is available for testing data links using PCM on commercial communication links. One possible method consists of using a PN sequence of say length 15. This modulates the link as shown in Fig. 2.

There are numerous ways of obtaining synchronization so that the local PN generator is in synchronism with the received sequence. One method is described by Springett.[**] By using sufficiently narrow bandwidth in the synchronizer system, PN synchronism can be maintained down to signal levels at which the PCM error rate is so high that the data are useless. It is so, of course, that it is necessary to keep the bit synchronizer and decision equipment tuned up to some well-defined performance level for this test. Just how to "spec" and test its performance will require some further thought. For example, for ground system performance criteria, it is not adequate to test bit synchronizers and

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[**] J. C. Springett; Command Techniques for Remote Control of Interplanetary Spacecraft. NTC Proceedings, 1962 Paper #8-4.

detectors in the presence of gaussian noise only because environmental noise such as impulse noise is frequently not gaussian and also the baseband noise in PCM/FM is not gaussian. Also in PCM/PM where the phase reference is obtained by phase-locked-loop, the loop error is not gaussian for low signal-to-noise ratios in the loop.[***] If pre-detection recording is used, it must be inserted before the carrier detector in Fig. 2. In this case, depending on the time base error in the pre-detector recorder, the loop bandwidth of the correlator in the PCM test pattern regenerator will have to be wide enough to track the time base error. This may cause no significant degradation in the test because the bit synchronizer will also have to have enough bandwidth to track the time base error. Further analysis is required to confirm this.

Type two mission In PCM this involves only the addition of the demultiplexer in Fig. 2. Since the demultiplexer accepts as its input the detected bit stream, it can be completely checked out by a PCM simulator. This is a standard part of the Apollo ground station, for example.

Insertion of the Test Signal

Ideally, the test signal should be injected in the far field of the antenna and the antenna swept through the angles to be encountered in the mission with <u>all</u> ground systems operating in mission configuration. This would test both the antenna feed and the amount of environmental noise picked by the lobes of the antenna.

A next best solution, which the writer has not heard of being tried, is to inject the test signal in through a hole in the dish or by some auxiliary radiator in an array. With such a feed, the antenna could be swept through the expected angles to determine if the criteria are satisfied for all angles. Some test work is required to evaluate this method.

Another possible solution is to put the test signal generator on an antenna pole. This solution is acceptable if the antenna does not pick up objectionable radiation from the ground and if other environmental noise picked up at different antenna pointing angles is found to be below the interference threshold.

In decreasing order of desirability are directional couplers and coaxial switches between the antenna and pre-amplifier. The least desirable is the insertion of the test signal at the multicoupler.

[***] W. C. Lindsay; IEEE Trans. on Aerospace and Electronic Systems, Vol. AES2 A, July 1966, page 393.

Recommendations

It is recommended that:

(a) the notch noise and bit error probability tests be made on an experimental basis on range equipment to determine its performance. On the basis of these results, the ranges should equip at least one telemetry receiving site with an operational version of this equipment and accumulate data on the basis of which criteria and test procedures can be written;

(b) use the results of (a) for expansion of IRIG Standards to include performance criteria and specification of tests for determining that the criteria are satisfied for each mission.

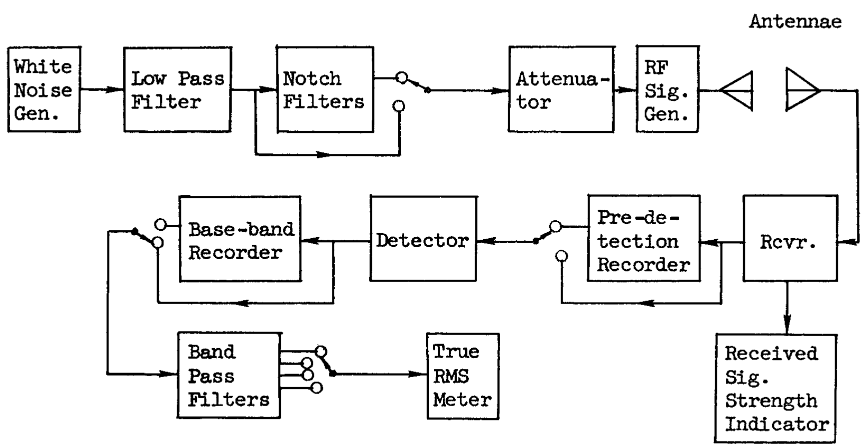

Figure 1. Notch Noise Tester

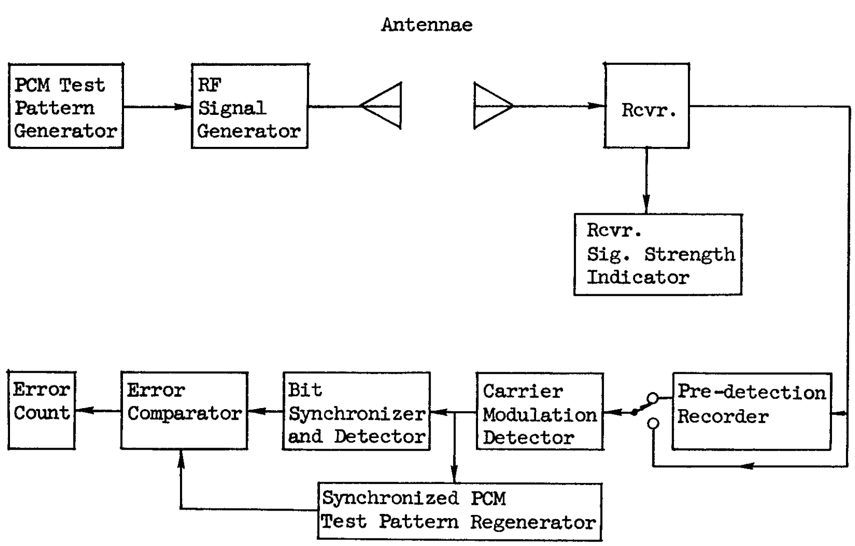

Figure 2. PCM Tester