

SPECTRUM STEWARDSHIP THROUGH BEST SOURCE SELECTION

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ABSTRACT

With the increasing demand on available frequencies used for Telemetry transmission, it is important for the test ranges to be good stewards of the spectrum. One method is a new use of Best Source Selection. This method consists of placing data-quality encapsulators at the output of each of the TM receivers used. This system works without the need to use pattern detect which allows for the use of Best Source Selection without the need for decrypting the data. In conjunction with new system architecture, this setup is how the Atlantic Test Range is using best source selection in the future.

KEYWORDS

Best Source Selection, Spectrum Stewardship

INTRODUCTION

The usable frequency spectrum for telemetry is shrinking in the L and S bands. Part of the solution to this problem is to augment the spectrum with the use of C-Band frequencies that were allocated for test purposes. Another important approach is to be good stewards of the spectrum that is currently available. One method of good stewardship is best source selection.

Best source selection assists in spectrum stewardship by significantly reducing incidences of dropped data during a flight. In practice, data loss is more likely to occur during the dynamic flight maneuvers of test points data loss causes test points to be repeated. Because of this, that flight takes up the spectrum it is using for longer periods of time. In this way, repeated test flight causes ripple effects which limit the spectrum available for future flights; as well as increasing the amount of time and money needed to complete testing. Best source selection saves programs time and money and also increases the available frequency spectrum by reducing repeated test points.

Many test ranges are currently using best source selection to help solve the problem of telemetry (TM) dropout. The current system at the Atlantic Test Range (ATR) at Naval Air Warfare Center Aircraft Division (NAWCAD) involves many lines and patches in the current manual patch panel system, as well as determining quality using a suboptimal system. The Telemetry Engineering team at the ATR has worked with GDP Space Systems to develop a new way to use the Best Source Selector (BSS) units using lessons learned from the current system. They also developed new system architecture to use with the new BSS. The new system will result in increased data quality and decreased setup time.

CURRENT SYSTEM SETUP

The current system uses a unit, manufactured by GDP Space Systems, that contains a typical Bit Synchronizer and a BSS, commonly referred to as just the BSS. With the current system architecture the BSS can be used in one of two ways, Pattern Detect and Analog. If it is possible to get all the signals being used back to the BSS as analog signals, the baseband output of a receiver, then it can run in Analog. This option develops signal quality information for both the long term, over several bits, and the short term, over only a few bits. This allows for the most effective use of the best source selection processes, of which there are a few options; one mode uses the long term data to pick a signal and follow it, which is called Best Source (BS), and one mode that compares the bits and votes on the current bit, which is called Majority Vote (MV). BS is a simple comparison of the quality of the signal, outputting the data on the best line at any given point. MV outputs a signal created by comparing each of the inputs' data bit by bit, and the bit that shows up the most is selected to create the output. These options are both usable with or without the quality information of individual bits.

The quality information provided with the data allows for the use of weighted best-source and weighted majority vote, resulting in increased data quality, as shown in Figure 1. This means that there is information on the quality of each bit, not just the overall signal, and allowing for

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individual bits to be left out if they are of poor quality. The desire to use weighted best source, which does not yield the same results as Majority Vote, comes from the situations where there are only two signals present. Even if the BSS is running in a majority vote mode with two signals present it automatically uses the best source or weighted best source as appropriate.

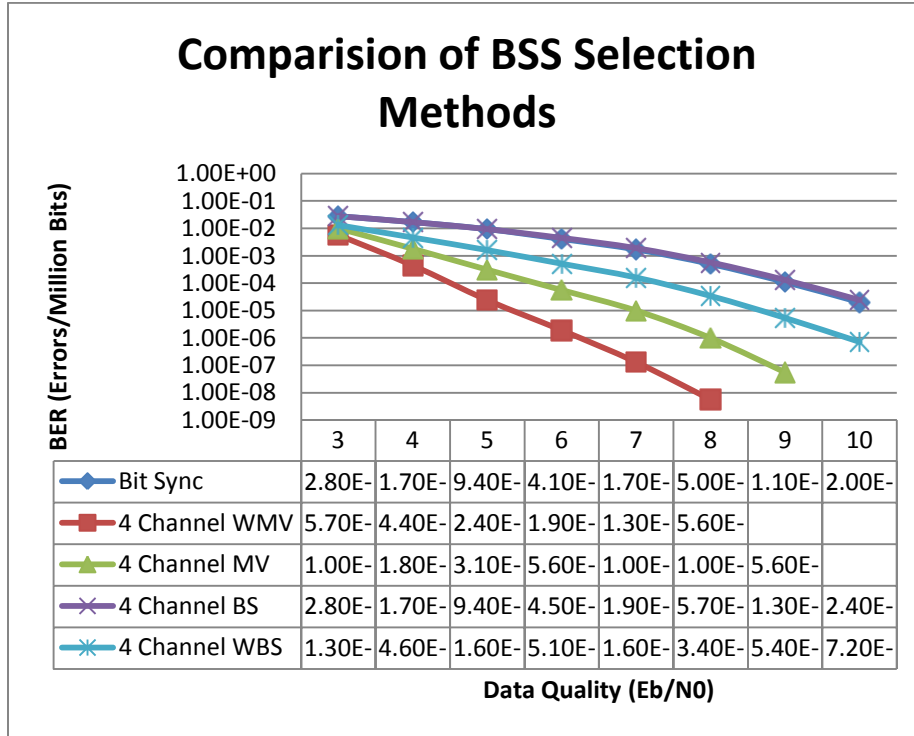


Figure 1: For Description of Test see Appendix A

In many instances, it is not possible to obtain the analog data for a stream being used, usually due to the distances to the antennas. In these cases, the current architecture can still be used, but not as effectively. This setup requires the use of pattern detect and decrypting the signals. The BSS can be used by looking at the sync patterns of the decrypted signals to develop a bit-error rate (BER) for the signal over time. Using this BER as the long term quality measure of each signal then the BSS can run the signals through either the best source or majority vote options. This method lacks advantages of having the quality information for each bit, and therefore cannot use the weighted options for selection. This issue also presents problems with resources, because it requires each stream to be decrypted before going into the BSS. This requires the use of a bit sync to be used prior to the decrypter for clock regeneration. Please see Appendix B for a flowchart describing the current setup and the decision tree for the current system.

LESSONS LEARNED

The current system can be improved in many ways, and the experience gained from implementing and using the current system brought the following issues up to be addressed;

- 1.) The need to be able to effectively use the current digital links from remote locations to the ATR. The earlier the analog signal can be converted to a digital signal the less impacted it will be by noise. If the data quality can be encapsulated prior to the sending the data back to the ATR then it would be available over all types of links. This will allow for the use of both Weighted Best Source and Weighted Majority Vote modes. These modes provide a greater increase in data quality than the non-weighted mode. Additionally, getting data quality from the signal will give a more accurate representation of the quality than a BER created from the frame sync pattern.
- 2.) The need to reduce the amount of equipment required to use the BSS. One of the biggest limitations on the system, and an area where it is impacting operations the most, is running in pattern detect. The need to use pattern detect stems from using the digital links back. Because each stream needs to be decrypted, the amount of equipment required grows quickly for additional streams. Since encrypted flights that aren't using the BSS still require decryption, it is currently not possible to run best source selection in every room the ATR can operate in.
- 3.) Each extra stream greatly increases the number of patches that must be made in current patch panel setup. Each stream requires at least two patches per line to get to the BSS, for unencrypted flights. The number of connections can get up to five per line for encrypted flights. A typical flight that needs pattern detect can have up to 21 individual patches. This number needs to be reduced because the greater number of patches increases the number of possible failures.
- 4.) The current BSS can handle Shaped-Offset Quadrature Phase-Shift Keying (SOQPSK) directly, but only by using two channels on the box, so if channel 1 is set to SOQPSK it uses channel 2 for the second input. Finding a solution to this will increase the number of channels that can be used per BSS as the flight test community moves towards using SOQPSK.

The lessons learned from using the system where used to address these issues. The solution was a new Best Source Selection configuration and the use of a new data switch to patch the data more effectively. This new system will decrease the setup time for flights while increasing data quality.

NEW BEST SOURCE SELECTION SYSTEM

Working closely with GDP Space systems, members of the Telemetry Engineering Section at the ATR came up with a modification to the original BSS design. These changes will help address the first two issues listed above. The change was to take the ability of the BSS to read in analog out of the unit and put in a separate unit called a Data Quality Encapsulator (DQE). This set up allows for the data quality capturing portion of the process to occur in close proximity to the receiver. Since each DQE is a four channel unit, they can be placed one to one with the four channel receivers currently in use by the ATR.

When the signal comes in the receiver will pull the signal out of the carrier and then output the analog baseband. If it is in SOQPSK then the I and Q signals will be output. The DQE takes in this analog data like regular bit sync then encapsulates the data into a new signal. This new signal is broken up into transfer frames that contain a header with a new frame sync pattern, followed by a value for the overall quality of the segment. After this header, the signal then incorporates the actual data interwoven with a number of quality bits depending on which type of encapsulation is in use. This number is either a quality bit for every regular bit in Type 1, or a quality bit for every four regular bits in Type 2. This signal is then sent digitally to the BSS. The BSS then decapsulates the signal and uses any of the selection schemes since it has data quality information.

This approach alleviates many of the issues associated with the current system. Firstly, the fact that the DQEs are at the antenna locations and output a digital signal allows for the current digital links to be used without preventing the optimal function of the BSS. The encapsulation process captures the data quality based on the analog signal, much like the current system when it gets analog inputs. Because of this, after decapsulating the signal, the BSS can run either the Weighted Best Source mode or Weighted Majority Vote mode. This results in a higher quality of data and less dropouts.

The use of encapsulation has an added benefit over the current system. Since the data quality decisions are made at the receiver, the BSS does not need a decrypted signal to be able to use best source selection techniques. This cuts down number of decryptors needed to use best source selection from one for each input channel to one for the BSS output; this output drives the telemetry front end. This also allows for the BSS to run on an unclassified system, since it only deals with data in the black. Finally, the DQE uses inputs 1 and 3 of a single channel to read in SOQPSK, which solves the fourth issue of the current system.

Using the encapsulation does have some draw backs. The ideal method requires a large amount of bandwidth to transmit the encapsulated signal. A typical 5Mbs signal encapsulated with type 1 encapsulation ends up with a bit rate around 11Mbs. These increases can put strain on the system, especially the links that are currently analog data channels. As more and more flights are conducted using encapsulation strains of high data rates will need to be addressed.

DIGITAL PATCH PANEL

One of the key advantages to the BSS is that it reduces the number of connections necessary to obtain data. Because only the BSS output needs to be decrypted, instead of each channel needing to be decrypted for pattern detect, as is the case currently. This reduces the number of data patches for equipment used in each setup, and allows for more linear data flow.

The patch system has been regarded as a single point multiple failure mode. This means that it is a single place where many failure modes exist: mis-patching by plugging into the wrong port, or leaving one or both ends un-patched; patch failure of the patch cord; patch failure of the port on the rack; “static” cable failure (cable that is permanently routed to the panel); a tech accidentally patching or un-patching a cable to a port, causing confusion and lost time and data. These myriad failures and confusion points have led to a search to better this patch system. After interviewing the technicians, Subject Matter Experts (SMEs), industry, and other ranges, a Digital Patch and control software system was designed and implemented. This Digital Patch system has many advantages over a physical patching system.

Among the many advantages of the Digital Switch, the lack of physicality is one of the most important. Moving all the switching into the digital realm allows control from anywhere in a network. This frees up floor space, and allows technicians to troubleshoot from anywhere. They are able to rapidly discern if changes made are effective or not.

Networking is advantageous because all technicians are able to setup and configure patches simultaneously. Before, a technician had to wait to get physical space to patch signals. A graphical interface, if written properly, can significantly reduce the number of patching errors, as it will prevent many common mistakes made today, such as patching input to input, output to output, or patching in the wrong order for proper data flow (e.g. BSS to Decryptor to Telemetry Acquisition System). A graphical system makes it easier to see data flow; patching to the wrong place will be easily caught by the technician.

A Digital Patch system is highly advantageous when systems fail. If a unit fails, a spare can be patched in and configured in a matter of seconds, all from the technician’s control station. This starkly contrasts with the current system. In the current system, after a failure is noticed the technician must leave the control station and move to the patch panel; they must find spare lines and a spare piece of equipment; re-patch it properly; then they must move back to the control

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station and configure the unit(s). The digital system allows all this to be easily preformed from one place, enabling rapid response to failures.

Being digital, it enables equipment to be placed closer together. These reduced distances allow for shorter cables. The shorter cables cost less to replace, but the biggest advantage is that reduced cabling reduces signal loss and Electro Magnetic Interference (EMI) has less cable to be introduced upon. This increases the signal integrity and reduces data loss and cross talk.

The Digital Patch Panel in the system is a 256 x 256 matrix switch, allowing one to one, one to many, or one to all style patching. This allows users to patch to many places at once for either a Piggy-Back room, or simply to have multiple outputs for each input, or whatever the user decides. The Digital Patch resides between the encapsulators and decryption systems of each room. This decision was made to eliminate the possibility of encrypted data co-mingling with decrypted data on the switch, and one feeding the other.

The switch has each encapsulator connected to it, and can patch to all 8 BSS units, with 16 input channels each. From the output of the BSS units, the four BSS selected outputs are directly sent to each telemetry room. This was done primarily due to the lack of space on the digital switch. Ideally it was desired to send the output of the BSS back into the Switch, so that one output can feed any or many rooms, but space would not permit that in this initial setup. A hot spare is also in the system, directly next to the active switch, and can be placed into service in a matter of minutes. This is there in the extremely unlikely scenario that the switch fails due to catastrophic events. The time required for the changeover is due to moving fifteen 30D connectors from the Active to the Hot Spare switch.

LOOKING TOWARDS THE FUTURE

Even as the new systems are being stood up, the ATR is constantly looking towards the future. In this case the short term focus will be on improving the function of the new best source selection and switching system. The long term focus is on what will be replacing it as the ATR moves towards the fifth version of the Real-time Telemetry Processing System (RTPS). While the short term is mostly infrastructure and data flow improvements, the long term plans will involve looking into completely new ways of moving the data.

The short term improvements will mostly be replacing the existing analog data channels back from remote sites with digital ones. This can happen because the encapsulators will be connected to every remote site and the only data coming back to the ATR will be digital. The digital links will allow for the use of higher digital bandwidth signals without any problems. The benefit of

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this is the ability to use encapsulation Type 1 over Type 2. Type 1 multiplies the input bit rate by approximately 2.2 because of the extra quality bit for each data bit, plus an overhead for a new sync-pattern and frame quality information. Type 2 only multiplies the data by approximately 1.4, due to one quality bit for every 4 data bits. While Type 2 does cut down on bandwidth used, it does not provide the improvement that Type 1 can provide, as shown in figure 2. The improved digital links back will allow the use of Type 1 encapsulation for all current and predicted data rates of supported missions.

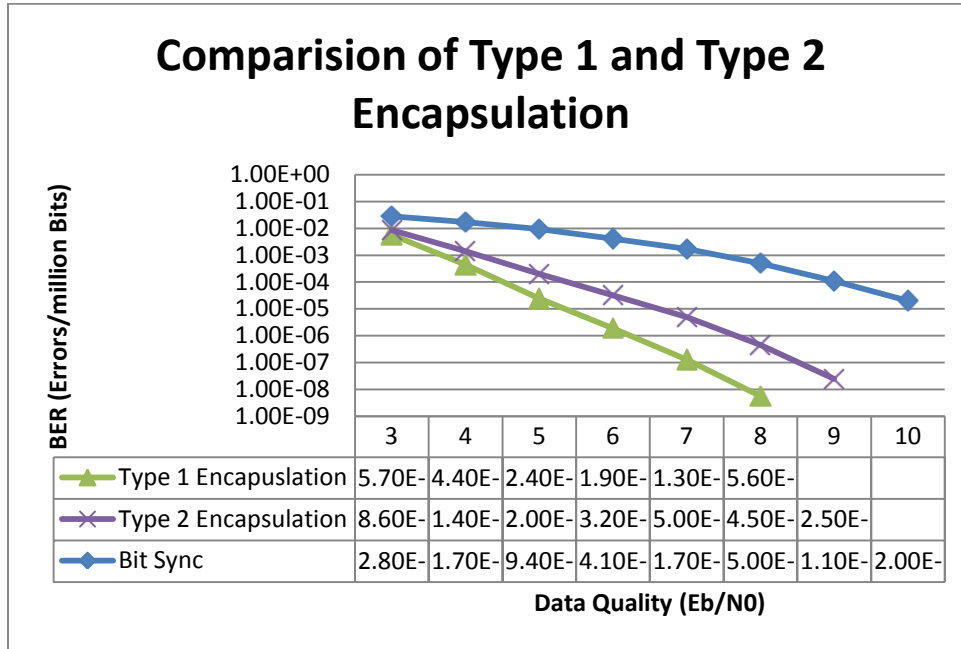


Figure 2: For an explanation of the test that resulted in this chart see Appendix A

Finally, as the ATR looks towards the long term it moves towards systems that will transmit their data uniformly over IP. This will allow the use of existing connections to run data back as well as command signals out. When this is achieved, the system will be able to be run off of a commercially available network switch. This will increase the stability of the system.

CONCLUSION

The best source system outlined above will provide significant increases to data quality while decreasing complexity of the setup. With a simpler patching system, an improved method to get the data back, and an increase in overall quality of the signal being output by the system, the new design should greatly decrease the amount of signal losses experienced due to multipath issues

caused by dynamic maneuvers. This will in turn increase the availability of the spectrum for use as it is not constantly being taken up by the need to repeat test points, as well as saving the government and the taxpayers' money by reducing the time it takes to run through the test process.

APPENDIX A

The test used to obtain figures 1 and 2 in the paper was conducted at Pax River by Grant Gerstner of the ATR and Steve Nicolo from GDP Space Systems. The set up was as follows: a simulator signal was sent out by a bit error-rate tester (BERT) which was copied into 4 signals. Then these signals were each delayed a different amount of time so that they would not be in line and injected with noise. This was to ensure that each signal was different. These noisy signals were sent into a GDP DQE box which was set up in the case of figure 1 for encapsulation type 1 and in the case of figure 2 set up as appropriate for the test. The encapsulated outputs were sent into a GDP BSS where they were decapsulated and the output of this BSS was sent back into the BERT. For the test procedure the BERT was set to a particular E_b/N_0 and then a reading was taken for the BSS and Bit Sync 1 from the BSS for a base value comparison. Test points were taken at E_b/N_0 s of 3-10, with readings taken after there was at least 50 errors in the signal. For some of the signals getting 50 errors in a reasonable amount of time was impossible due to signal quality, in which case these values were left off. For the test that resulted in Figure 2 the selection method was weighted mean value, and 4 channels were used. More information from this test is available on request.

APPENDIX B

The Data Flow and decisions for the current system set up can be seen below in figure 3. It shows the data from the receiving antennas to the operators in the Project Engineering Stations (PES).

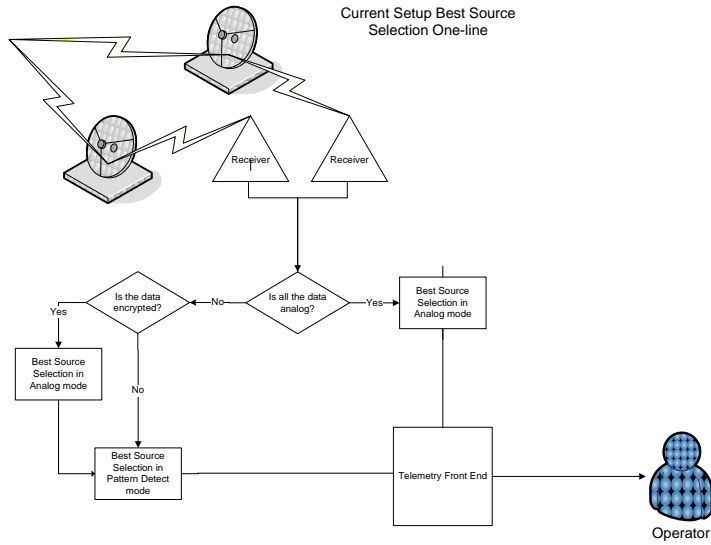


Figure 3

APPENDIX C

The data flow and decisions for the future system can be seen in figure 4. It shows the data flow from the antennas to the PES.

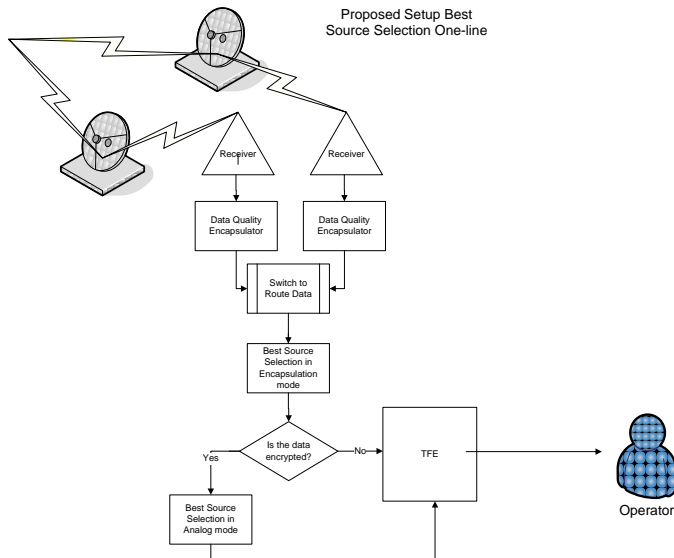


Figure 4