Translation of L and S Band Tracking Assets to X Band

High Dynamic Testing

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ABSTRACT

Recent Constraints on the use of L and S band spectrum led to the search for additional Frequency Domain Bandwidth augmentation for test range telemetry needs. The ITU (International Telecommunications Union) approved X band region is listed as 7000 MHz to 8500 MHz for telemetry space applications. Bandwidth is available within this domain subject to the WARC (World Administrative Radio Consortium) approvals. This paper describes tests and presents results illustrating methodology that is available, and which can be used for conversion of S-band assets to the X band spectral region.

KEY WORDS

X-band tracking system, S-band tracking system, high dynamics tracking, L and S band spectrum, MTS, NSROC

INTRODUCTION

The modifications to the S-band tracking system for this test have been described in a number of previously published papers, (see references). Some of the "history" is necessarily reiterated here to facilitate in the description and results of this particular high dynamics test. The test described herein is representative of the extreme testing that a tracking system must undergo successfully to be considered as a useful test range asset for the tracking of any high dynamic targets such as rockets and missiles. This test description and results should verify and solidify earlier hypotheses, that the system would be usable at the frequency(s) of interest.

Most tracking systems function within very specific frequency bands in order to allow for necessary design parameters that provide the desired functionality of the tracking system.

Attempts to operate “so designed” systems outside these specified parameters are generally futile without serious system modifications. The system of concern in this exercise was originally designed to track in the L and S band, 1440 - 1540 MHz, 1710 - 1850 MHz, 2200 - 2400 MHz, military and space systems frequency region allocation. Various parameters such as F/D ratio, parabola design and material choice, crossed dipole antenna length, antenna axial ratio, allowable crosstalk, and RF feed frequency band-pass are all examples of parameters that the designer must consider, and hold within certain tolerances if the system is to maintain track on a highly dynamic signal. This experiment was designed in part to move the tracking and RF receiving capabilities of the tracking system from L and S band to the X band (7.975 Ghz). The RF feed on the modified system was designed by and procured from VIASAT, which was also the procurement source for the original Mobile Telemetry System (MTS) L and S band tracking system.

In the exercise of routine performance of “Missile Range” telemetry data gathering, exercising a tracking systems’ high dynamic tracking ability forms an essential quality check of that tracking systems ability to gather telemetry data. A series of low dynamics preliminary tests were conducted with the modified system to incrementally “step” the system and test process up to the tracking dynamics regime that the system would eventually be required to perform within. These tests included stationary targets and fixed wing aircraft. The fixed wing aircraft tests were conducted at various elevations and azimuths to assist in precipitating any possible anomalous geometric arenas with respect to the tracker. It was observed in these tests that low elevation angles and high signal levels at any relative geometry contributed to loss of tracking lock and saturation of front end LNA’s (Low Noise Amplifiers) and Telemetry receivers[1]. In general, however, the tests were very successful, as judged by the analyzed data and as witnessed by tracking systems experts (government, and industry) who were participants in, and observers of the tests.

The X-band tracking method of choice was arrived at by considering a number of possible avenues beginning with a mild redesign, and working up to a complete new antenna tracking system. Fiscal constraints limited the approach to a simpler and less expensive redesign of the feed and servo control to receive and process X-band RF. The design and early testing of antenna feed and servo parameters progressed from initial factory acceptance (antenna range tests) to “live” (moving target) range tests at WSMR (White Sands Missile Range) in May of 2005. Proof of concept was realized with range testing on static targets (bore site tower testing), and with low dynamic tracking of aircraft equipped with an X band CW (Constant Wavelength) emitter. After this series of flight tests were completed it was collectively decided that the test asset and test process maturity was at a point where a step “up” to a high dynamic vehicle track could be attempted. For this high dynamics test WSMR tracking assets and an Enhanced ORION, a highly dynamic exo-atmospheric research rocket would be utilized. The vehicle dynamics (acceleration, terminal velocity, spin rate, launch on command) were all parameters that were pre-considered and utilized in the testing of the X-band tracking system.

The tracking system (in a general block diagram form, FIG. 1) was arranged as shown below.

It can be seen from the diagram that the changes to the system were minimized to the greatest extent possible which allowed for the rapid change over to X band, and of course, the change back to L & S band. The diagram also illustrates the method that remained unchanged and available for the recording of AGC's as S and L band detected levels directly out of the receivers.

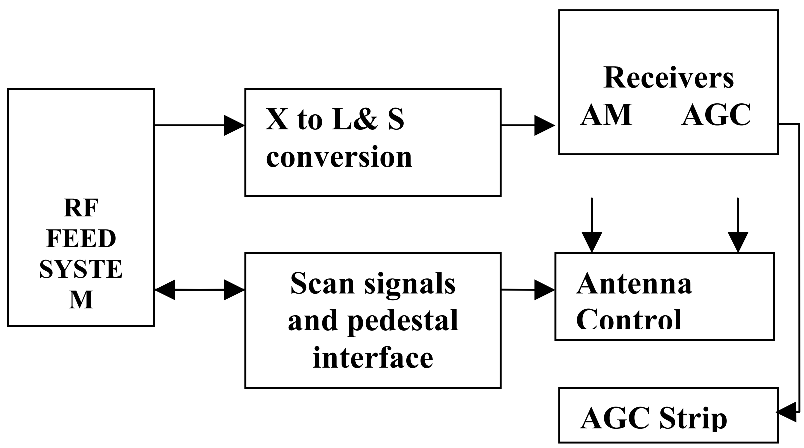

Fig.1: *Tracking System Block Diagram*

TEST STRUCTURE

NASA Research Rockets uses a structured numbering system to refer to individual tests performed by NSROC/WSMR. This particular test was identified as 30.071/Winstead M./WSMR 2005 in the NSROC documentation[3]. This reference is useful if particular flight information on the vehicle or the actual flight parameters require reference. It is possible to access this flight information at the NSROC web site (www.nsroc.com) with proper credentials. The test structure was (originally) to involve exactly the same tracking system as had been used on the previous lower dynamics testing. This was changed at the last minute, as the MTS was relegated to higher priority work a significant distance from the scheduled flight area. A number of difficulties would have been introduced into the test had the decision been made to retain the use of the same tracker as used previously on lower dynamics tests. The change in tracking system was demonstrative of additional capability and something of a testament to the diverse adaptability of WSMR, in conjunction with VIASAT, to use the feed system on any of the same type tracking systems on very short notice.

The tracking system that the feed was attached to is referred to as J-13 at WSMR. J-13 is a fixed tracking asset with an 8 foot aperture originally procured from VIASAT. It is also the same type of system as used on the earlier testing, and is located at the Range

Control Center at WSMR. At T-1 day J-13 was quickly reconfigured to the X-band tracking feed, and the reconfigured antenna control unit was put in place by WSMR and VIASAT personnel. The test infrastructure for the X band portion of the test only allowed for that one tracking asset, and hence it became extremely important that this tracking asset was functional and in place for the test.

The difficulty in performing this change the evening before the test can be imagined. There were no preprogrammed flight characteristics available for the flight and there was no external pointing data available from RADAR or any other sources so the tracker would have to perform in a "hands off" auto track mode to meet the data collection requirements of the test. Therefore the test required a valid signal level from the launch vehicle throughout the flight. In turn the tracker would demonstrate the capability to autotrack the signal as received from the vehicle on the ground (at least in azimuth), and then demonstrate the ability to auto track the vehicle from T-0 until loss of signal. Furthermore it would be necessary to demonstrate that the tracked signal was able to provide recoverable data in the realtime as well as in the post flight data reconstruction frame of reference.

The Fig. 2 plot indicates the data lock condition prior to, at T-0, and during flight[2].

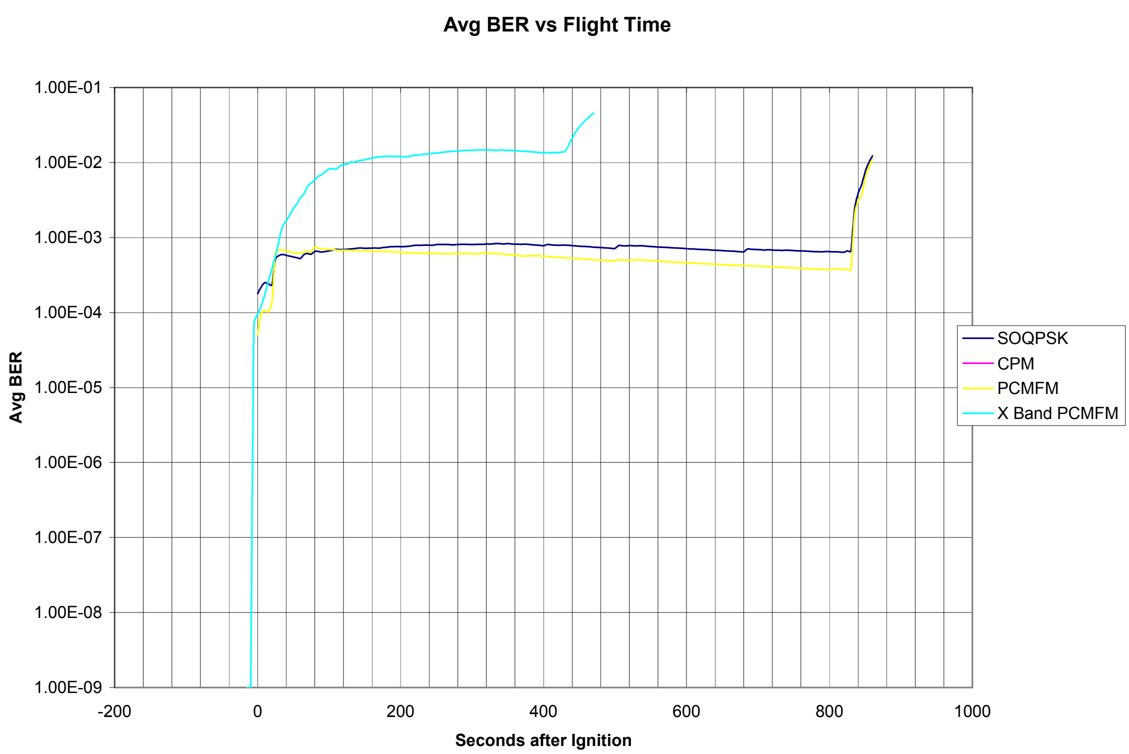

Fig. 2: *Average BER vs Time plot*

The figure indicates that near perfect X band signal lock was achieved prior to launch, and along with the SOQPSK, CPM, and the S-band PCM /FM, the X band signal as received was able to achieve a BER better than 1 error in 10^9 bits (avg.). At T-0 as the vehicle left the pad and began to rotate the BER decreased to the value of one error in 10^4 bits. As distance from the tracker increases the signal decreases, and the BER continues to degrade, until it fades out at 400 + seconds. The BERS on all links were predicted to be 1E-1 (worst case) due to a conductive strip antenna modification, but the actual average performance of the system is seen to exceed this (worst case) predicted value. The difference between the X- band and the S band signals can be attributed to the lower transmitted power on the X-band transmitter compared to the S band transmitters, and the difference in the tracking systems receiving antenna sizes, 8 ft. for the X band, and 32 ft. for the S band. Actual down converted X band signal levels (as AGC values from S band receivers) were recorded, but were not available at the time of publication of this paper and may be forthcoming at a later date.

CONCLUSIONS

Although additional testing is needed to quantify all regimes, X band conversion of S band tracking assets is not conjecture or a technically debatable issue at this point in time. If there is a migration of spectrum to the X band region, existing assets can be economically converted to track in this domain.

RECOMMMENDATIONS

Additional tests of this nature are recommended to test all features of both the frequency migration to X band, along with newer modulation formats and older tracking assets, which have not been tested at all in this way. In the authors experience there is no substitute for a test series which requires a system to be ready to meet a T- 0 timeline, and also exercises all tracking functions of a system in the extreme. Obviously there will be shortcomings or additional expenses on tracking systems that are not equipped with solid reflectors, or which may not be able to be re-designed for higher frequencies. These shortcomings need to be identified, if for no other reason, to catalog and understand the cost of future change over modifications to X band.

ACKNOWLEDGEMENTS

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3. NASA Sounding Rocket Operations Contract (NSROC), Targets and Special Projects Office Flight Readiness Review, 30.071/Winstead M. WSMR 2005, prepared by William Payne, available from www.nsroc.com

4. Additional information on the tracking system modifications are also available from VIASAT corp. Refer to ARTM PRDA-03-01-PKD.