ADVANCED TEST RANGE VERIFICATION AT RF WITHOUT FLIGHTS

Steve Williams
RT Logic

ABSTRACT

Flight and weapons test ranges typically include multiple Telemetry Sites (TM Sites) that receive telemetry from platforms being flown on the range. Received telemetry is processed and forwarded by them to a Range Control Center (RCC) which is responsible for flight safety, and for delivering captured best source telemetry to those responsible for the platform being flown. When range equipment or operations are impaired in their ability to receive telemetry or process it correctly, expensive and/or one-of-a-kind platforms may have to be destroyed in flight to maintain safety margins, resulting in substantial monetary loss, valuable data loss, schedule disruption and potential safety concerns. Less severe telemetry disruptions can also result in missing or garbled telemetry data, negatively impacting platform test, analysis and design modification cycles.

This paper provides a high level overview of a physics-compliant Range Test System (RTS) built upon Radio Frequency (RF) Channel Simulator technology. The system is useful in verifying range operation with most range equipment configured to function as in an actual mission. The system generates RF signals with appropriate RF link effects associated with range and range rate between the flight platform and multiple telemetry tracking stations. It also emulates flight and RF characteristics of the platform, to include signal parameters, antenna modeling, body shielding and accurate flight parameters. The system is useful for hardware, software, firmware and process testing, regression testing, and fault detection test, as well as range customer assurance, and range personnel training against nominal and worst-case conditions.

NOTE

This paper is a placeholder in a sense, since it describes the general functions of an RF Channel Simulator-based RTS. By October, 2010, a substantial update to this paper will be available, including specific test results from a major U.S. test range. A summary of the expanded paper will be presented at the 2010 International Telemetering Conference in San Diego, CA, October 25-28, 2010. Copies of the final paper will be available from the author after the conference.

KEYWORDS

Range Test System, Channel Simulation, Telemetry Site Test, Range Control Center Test, Range Testing at RF.

TYPICAL RF CHANNEL SIMULATOR USES

RF Channel Simulators are experiencing increased utilization in R&D, test and training activities due to their ability to produce accurate RF signals that precisely match those that will be encountered when receivers and transmitters are at distance, and in motion with respect to one another. At distance and in motion, RF links are impacted by carrier and signal Doppler shift, path delay, path loss and noise. Such links can also encounter disruption due to interference, both accidental and intentional, terrain, weather, antenna boresight misalignment, body shielding, insufficient transmitter power, and improper selection of data rate, frequency or modulation type, to name several. The RF Channel Simulator reproduces such effects with extremely high fidelity, rendering such instruments vital test tools that accurately substitute at RF, for distance and motion.

Typically, RF Channel Simulators are used in a laboratory environment for hardware-in-the-loop testing of transmitter systems and receiver systems as shown in figures 1, 2 and 3 below. Such setups are useful for hardware (RF, analog and digital), software and firmware testing, to include automated regression testing.

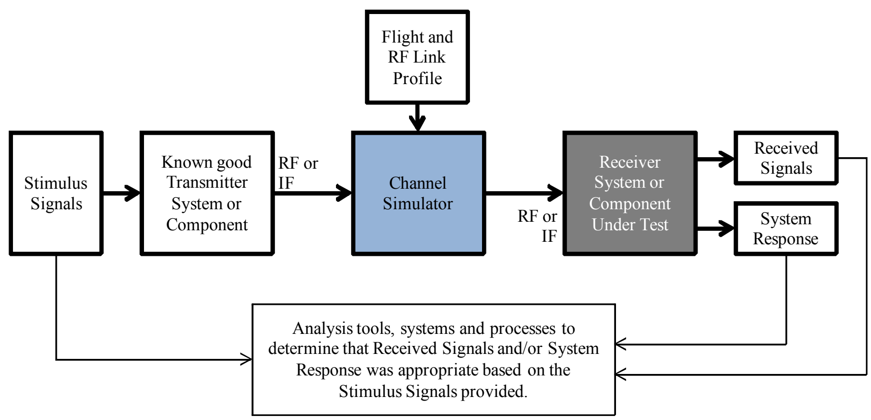

Figure 1. Use of Channel Simulators to test Receiver Systems.

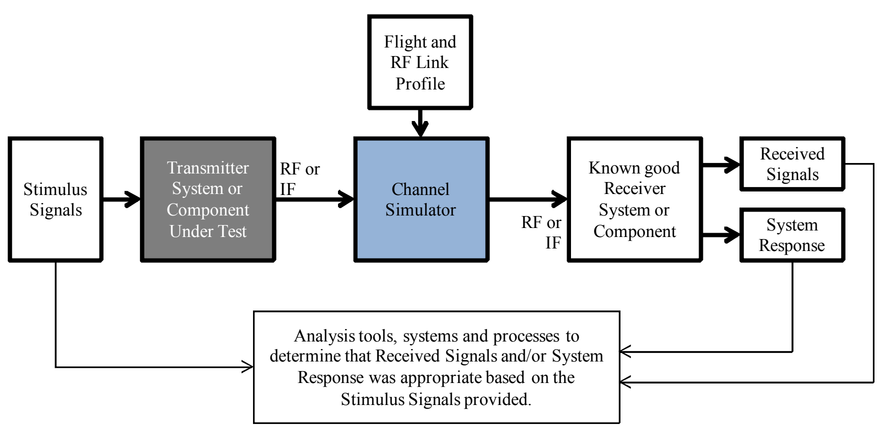

Figure 2. Use of Channel Simulators to test Transmitter Systems.

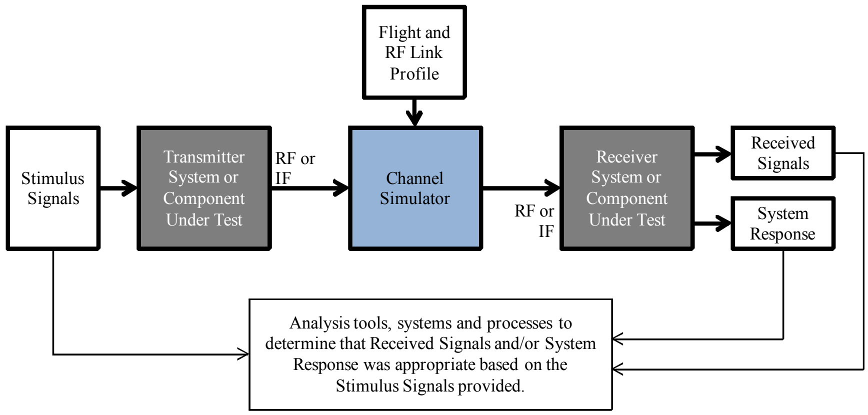

Figure 3. Use of Channel Simulators to test Receivers and Transmitters as a system.

A typical example application is in Adaptive Coding and Modulation (ACM) Satellite Modem test as shown in Figure 4. With ACM modems, link behavior encountered in real time results in communications between the modems to dynamically adjust parameters such as their transmit power level, modulation scheme, data rate, error correction code utilization, and others.

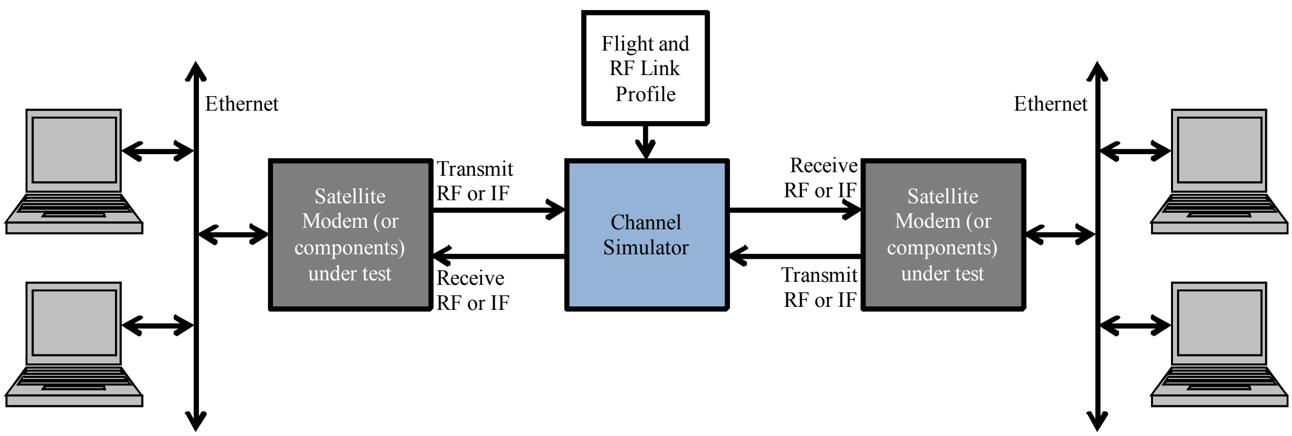

Figure 4. Typical Channel Simulator application to test Satellite ACM Modems.

By providing "Flight and RF Link Profile" scenarios that control the Channel Simulator appropriately, RF link performance between the two modems can mimic intended missions, both nominal and worst case. Additionally, the channel simulator can create link conditions that would not appear in nature, but that are needed to stress the limits of modem hardware and/or firmware algorithm response. The test setup of Figure 4 simulates the planned operational scheme of Figure 5.

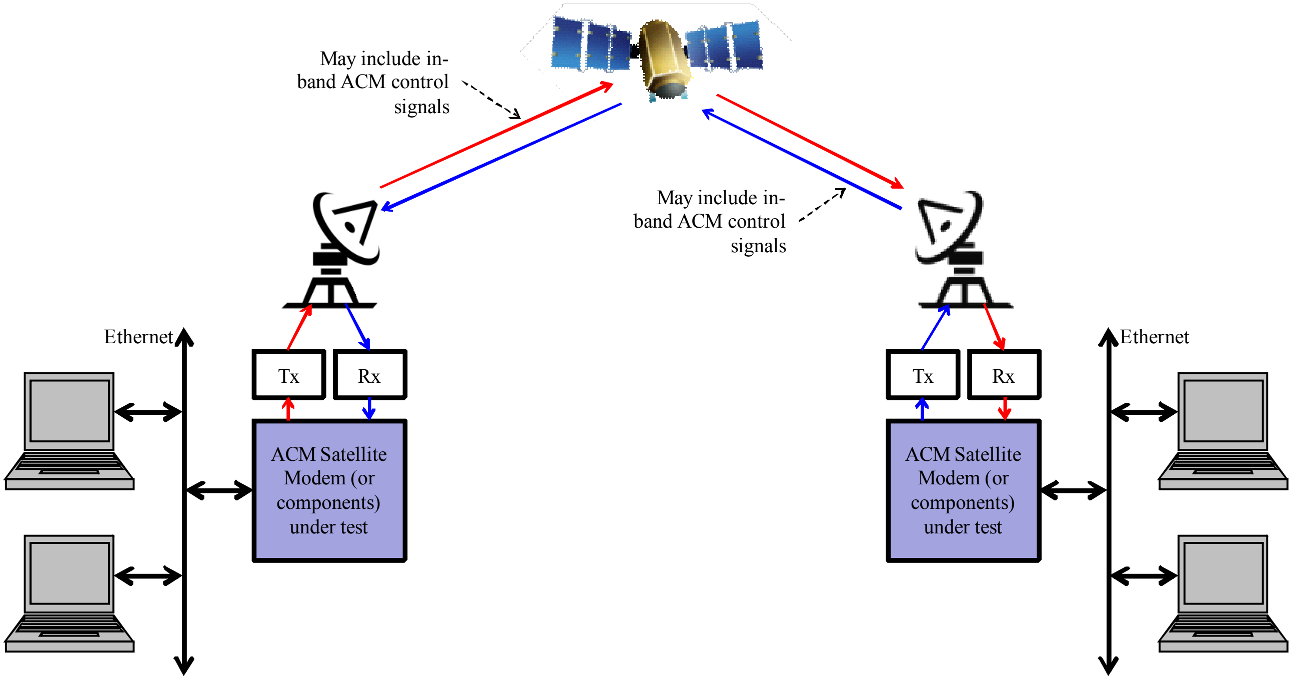

Figure 5. Example operational scheme for Satellite ACM Modems.

RF CHANNEL SIMULATOR FUNCTIONS

The most important attribute of a Channel Simulator is its strict adherence to the laws of physics. Failing that, the Channel Simulator cannot produce realistic RF effects. In the worst case, this may result in data errors introduced by the instrument. Or, instrument output signals may be stepped, rather than smooth and spectrally clean, leading to false conclusions regarding the device under test.

To input signals, Channel Simulators add flight path-related and frequency-related Doppler shift (both carrier and signal Doppler shift), path loss, delay, noise (additive white Gaussian noise, AWGN in most cases) and interference (intentional and accidental). The output signal from the Channel Simulator is the same as the input, but with these perturbations added. Most RF link effects can be simulated by controlling one or more of these parameters in time.

RANGE TEST APPLICATION

When a Channel Simulator is programmed with the flight path of a missile flying on a test range, for example, it can generate signals that precisely replicate those that would be received from the missile at any specific TM Site. The Channel Simulator output signal will include the same terrain dropouts, link budget dropouts, Doppler shift, path loss, delay and noise as will be received by the TM Site on the actual signal from an in-flight platform. The use of a channel simulator provides these signals without flights being required.

Figure 6 is a simplified block diagram of an RTS that stimulates a single TM Site.

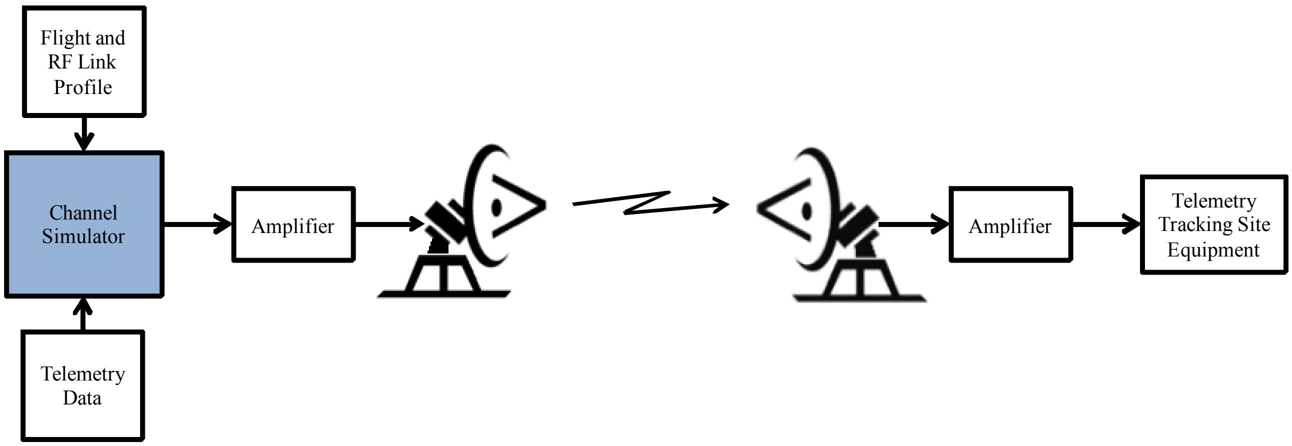

Figure 6. RTS for Single TM Site Stimulation.

In Figure 6, Channel Simulator inputs include a Telemetry Data file representing the data that will be sent from the vehicle flying on the test range. This data should be as close to the data that will actually be transmitted as possible, perhaps even data from a prior flight of the same vehicle, since representative data within the Telemetry Data stream enables proper displays and other functions at the TM Site and/or the Range Control Center.

The Telemetry Data should contain accurate flight vehicle position and time information as well, since this will be used by the RTS to generate the flight profiles that eventually control the Channel Simulator's application of Doppler shift, path loss, delay and noise. Position information generally includes latitude, longitude, altitude, yaw, pitch and roll.

When position and time information is provided, a flight path scenario can be developed for the Channel Simulator. This time-oriented, three dimensional flight path mimics an actual prior flight, or a planned future one as shown in figure 7 below.

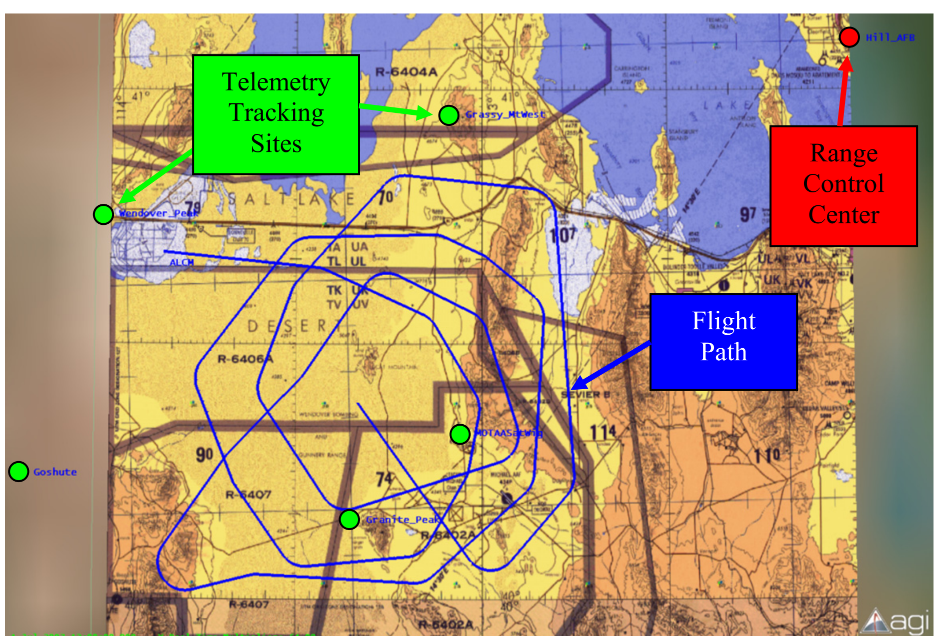

Figure 7. Channel Simulator Flight Path Setup.

Yaw, pitch and roll, are combined with antenna pattern information, antenna mounting location(s), and overall surface shape so that the Channel Simulator can generate output that includes antenna pointing and body shielding factors.

When TM Site locations are added, along with their antenna patterns, range terrain information and additional RF link characteristics, the Channel Simulator can create signals that match those that would be received at each TM Site from the in-flight vehicle.

Plotting range vs. time for three TM Sites, for example, results in the plot of Figure 8. Each site is a different color on this plot. Interruptions in the traces are dropouts associated with terrain, link-budget, body shielding or antenna patterns.

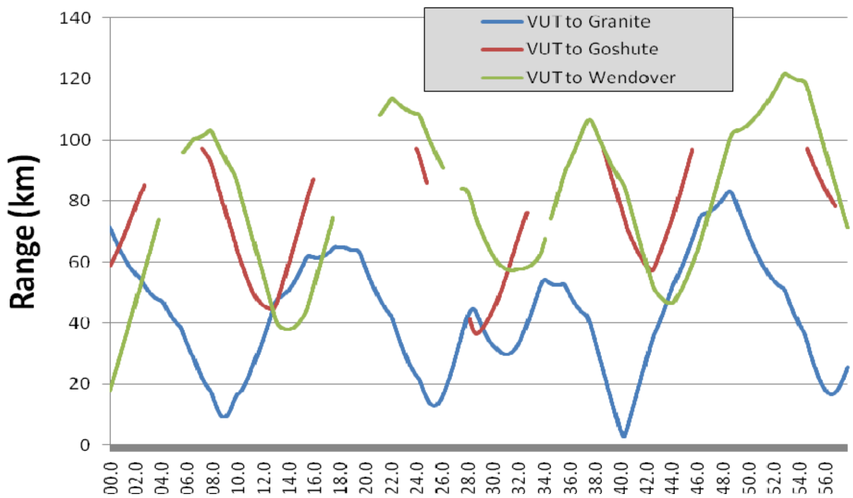

Figure 8. Elapsed flight time vs. range between flight vehicle and 3 TM Sites.

The RTS uses this range vs. time information to generate a separate signal delay profile between the in-flight vehicle and each TM Site as shown in Figure 9.

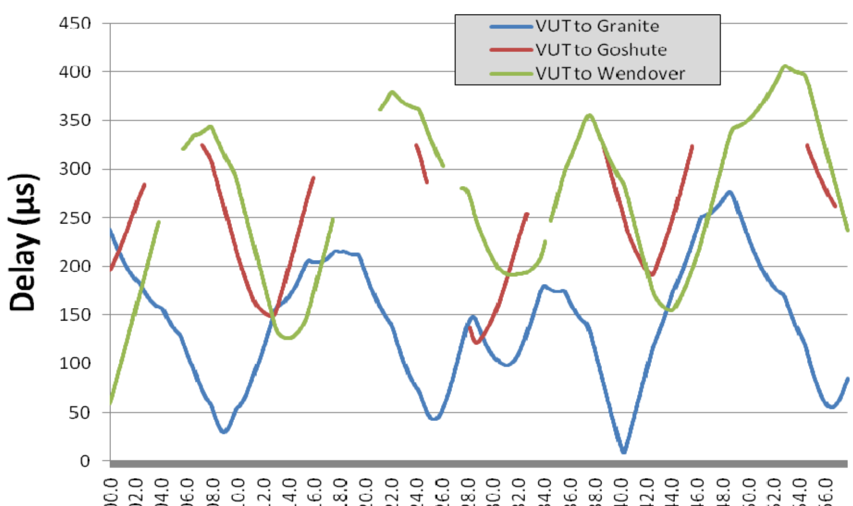

Figure 9. Elapsed flight time vs. range delay between the flight vehicle and 3 TM Sites.

Similarly, the RTS creates path loss and Doppler shift profiles between the flight vehicle and the modeled TM Sites as shown in Figures 10 and 11 below.

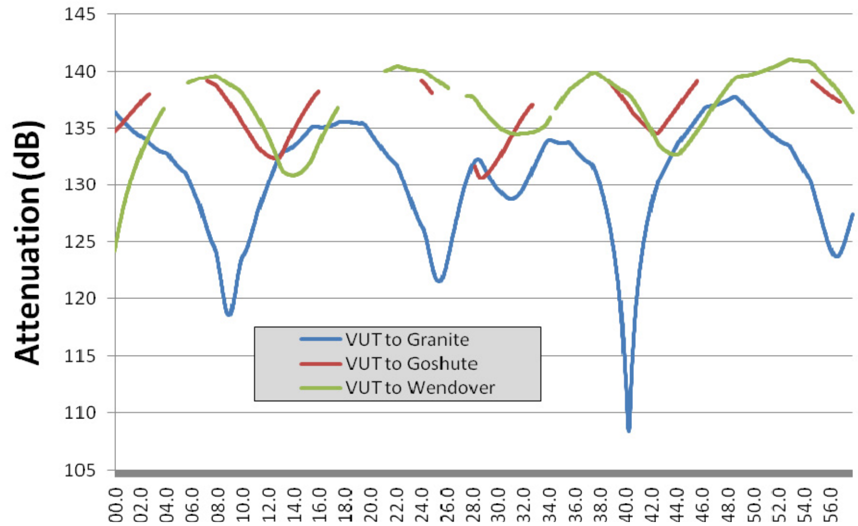

Figure 10. Elapsed flight time vs. path loss between the flight vehicle and 3 TM Sites.

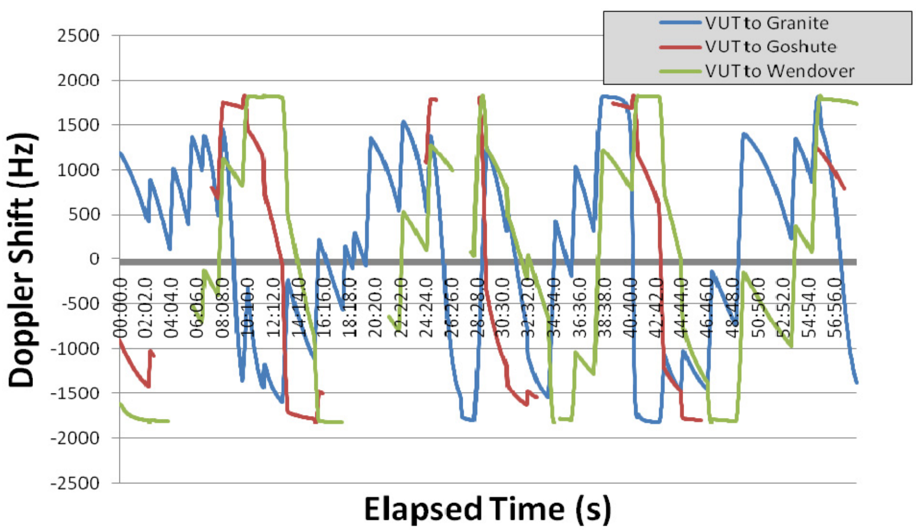

Figure 11. Elapsed flight time vs. Doppler shift between the flight vehicle and 3 TM Sites.

Expanding Figure 6 to stimulate multiple TM Sites simultaneously results in the RTS shown in Figure 12.

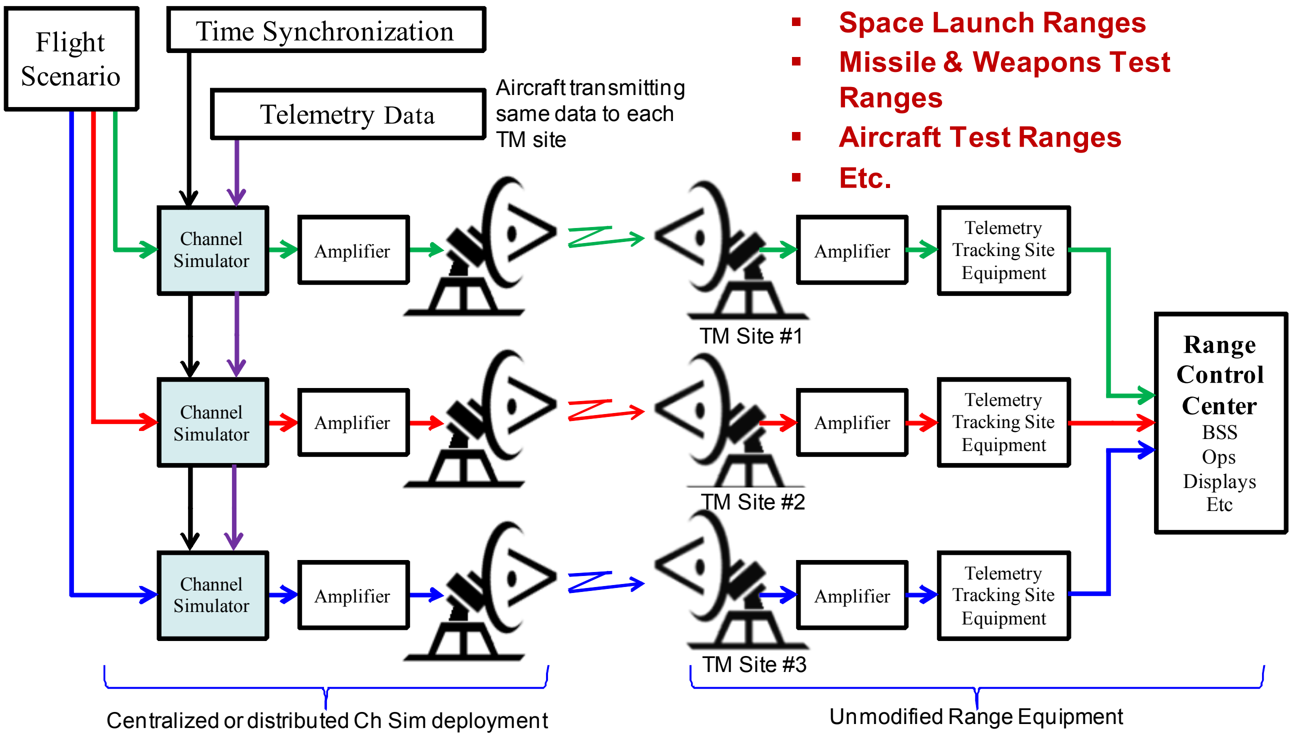

Figure 12. RTS configured to stimulate 3 TM Sites simultaneously.

Common telemetry data is provided to each channel simulator, so that all three synchronously output the same base signal to each TM Site as would occur with a test vehicle flying on a range. Based on the flight scenario inputs however, this common base signal will be modified with different Doppler shift, delay and path loss based on the dynamic spatial and RF relationship between the in-flight vehicle and each TM Site as shown in figures 8-10.

The resulting signal is amplified, the transmitted to distant TM Sites from dedicated RTS antennas. TM Sites receive these RTS signals, and perform all other processing, including transmission to the RCC without knowledge that the received signals are from the RTS instead of an actual in-flight vehicle. The only significant difference in TM Site operation under the RTS vs. an actual flight, is that the TM Site antennas do not follow the in-flight vehicle, because there is none. Instead, the TM Site's antenna remains trained on the RTS transmission antenna associated with that TM Site.

Similarly, the Range Control Center performs its functions fully as if an actual test was being flown.

DEPLOYMENT

Centrally located Range Test Systems can transmit high-power RF signals across range distances to multiple TM Sites, simultaneously or sequentially, with each TM Site receiving signals with appropriate RF perturbations as described above.

Mobile Range Test Systems can transmit to several TM sites at RF, and then be repositioned to transmit to others.

Alternatively, Range Test Systems can be temporarily or permanently installed at each TM Site, and connected at IF, or low-power RF into TM Site antenna calibration lines or directly into TM Site receiver systems.

Time synchronization, if necessary, can be accomplished post-acquisition, or by the simultaneous trigger of multiple RF Channel Simulators within the RTS. Range Test Systems can be controlled locally or remotely via hard wire, fiber or wireless Ethernet.

CONCLUSION

Based on RF Channel Simulator technology, sophisticated Range Test Systems can be constructed for the purpose of range test, verification and training. RTS systems ensure range and range asset functionality, performance, and mission readiness. RTS systems can typically verify;

- TM Site operation as a whole,
- TM site hardware, software, and/or firmware component operation,
- The path from TM site to the RCC,
- RCC functions, including best source TM selection, and
- Range-customer output generation.

Range Test Systems enhance range personnel and customer confidence in the success of a mission to be flown, reducing associated time, cost and risk. They also provide significant regression test and compatibility test opportunity, assuring continued range functionality when range equipment, software, firmware or processing algorithms are modified.

Range Test Systems can assist with range training missions, as they provide full range functionality without actual flights being required. Such training "flights" can be conducted under nominal conditions, or with injected mission impairments.

REFERENCES

Williams, Steve, "RF Channel Simulators Assure Communication System Success through Hardware-in-the-Loop Testing," SpaceOps 2010 Conference, Huntsville, Alabama, April, 2010. Some portions of this paper are used here with permission, and are Copyright © 2010, American Institute of Aeronautics and Astronautics.

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