Broadband GPS Data Capture for Signal and Interference Analysis

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BIOGRAPHY

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ABSTRACT

There is growing concern regarding the ability of GPS receivers to operate in the presence of in-band or near-band interference. In-band interference can occur deliberately from GPS jammers or naturally from spurious harmonics from nearby electronics that generate signal products that land in the GPS signal band. To support development and testing of GPS receivers in an interference environment, NAVSYS has developed a broadband GPS signal simulator product which includes the capability to either record live satellite signals during testing or generate simulated signals using the NAVSYS GPS Signal Architect software, and play these files back to generate simulated GPS RF signals for receivers under test. This product allows for broadband capture of the full GPS spectrum and also recording of interference environments. In this paper, we describe how this GPS signal simulator product will also allow during playback for a user to insert interference signals into recorded or simulated GPS signals in a non-jammed environment for testing of a GPS receiver in a simulated interference environment.

INTRODUCTION

Near-band interference can occur from other close-by transmissions that are higher in power than the GPS received satellite signals. One example of this is the wireless network that was proposed to be deployed by LightSquared[1]. As a result of extensive testing with LightSquared broadcasts by the National Space-Based PNT System Engineering Forum (NPEF), the National Telecommunications and Information Administration (NTIA) and the Federal Aviation Administration (FAA)[2], it was determined that these transmissions would, in fact, effect many existing GPS receivers.

To show interference between LightSquared and GPS required testing to be conducted using a wide variety of different GPS receiver types at a number of different special purpose facilities provided by the Department of Defense (DoD) and federal labs. These facilities were selected as they had sophisticated signal simulation capabilities to generate both the GPS and the LightSquared signals and also had anechoic chambers to allow broadcasting these signals to receivers under test (see Figure 1). Live testing was also conducted in New Mexico and Nevada (Figure 2 and Figure 3) to evaluate the effect of interference on first responders' use of GPS[3].

Figure 1 NAVAIR Anechoic Chamber

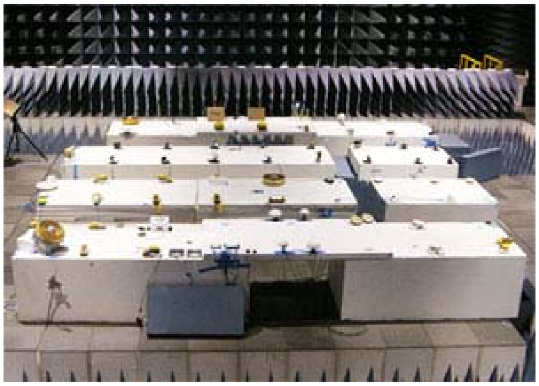

Figure 2 NPEF Test Setup at White Sand Missile Range (WSMR)

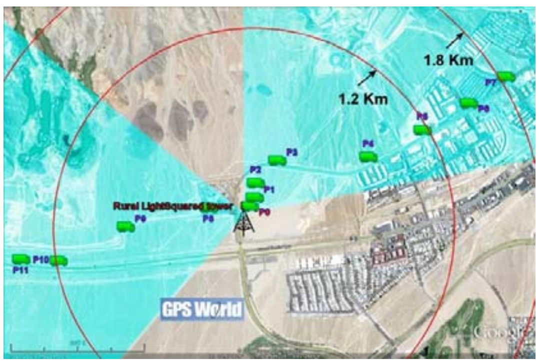

Figure 3 Boulder City, Nevada, E-911 Tests

As a result of the testing, the Federal Communications Commission (FCC) Office of Engineering and Technology has established a workshop on spectrum efficiency and receivers to discuss the characteristics of GPS receivers and how their performance can affect the efficient use of spectrum and opportunities for the creation of new services. Key topics included current practices for receiver design, case studies involving interference due to receiver characteristics, and approaches for promoting interference avoidance and efficient use of spectrum, given the current receiver base and potential future deployments[4].

The LightSquared interference testing involved a large number of different organizations and receiver manufacturers and was extremely expensive, both to set up the tests and to collect data for evaluation the effect of this interference on different GPS receivers under representative conditions. While this test method provided conclusive data to show the problem, this approach for verification and validation of interference would be expensive to continue due to the different permutations of receiver types and potential GPS interference sources. An alternative method for performing testing and analysis on the effect of interference on GPS receivers is to use broadband data capture and playback, as described in this paper.

INTERFERENCE TESTING ALTERNATIVES

In Figure 4, an example test setup for performing interference analysis is shown which is similar to that employed during the LightSquared testing shown in Figure 1. A signal generator is used to build the simulated RF interference signal, which is then mixed into a received live GPS satellite signal. The combined GPS and simulated interference signal is then reradiated to GPS receivers under test. A reference receiver can be used to track the baseline live GPS signal as a point of comparison.

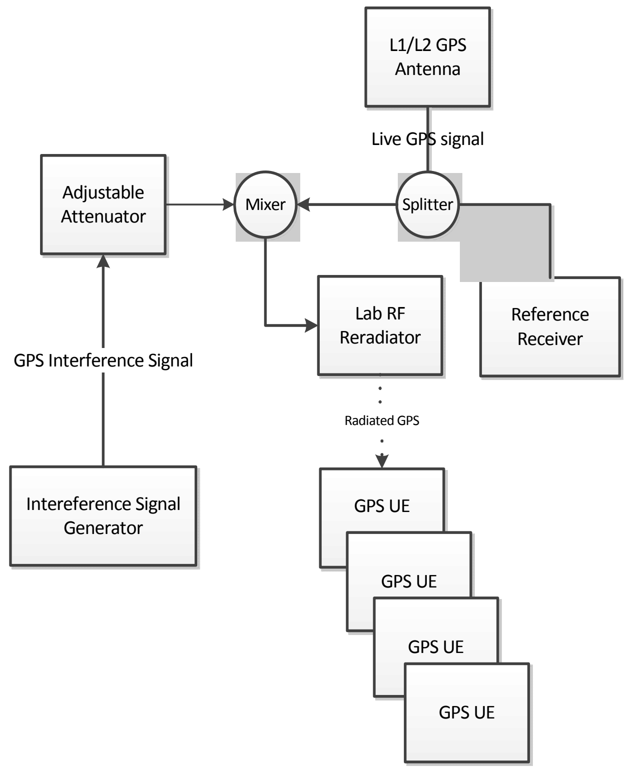

Figure 4 Interference Testing – Rebroadcaster

An alternative method for setting up a GPS + interference test is to use digital signal generation and a digital record and playback capability. In Figure 5 we show the GNSS Signal Architect product suite that includes the capability to capture full bandwidth GPS signals as Digital Storage Files (DSF) that can be played back through an RF remodulator into GPS receivers under test.

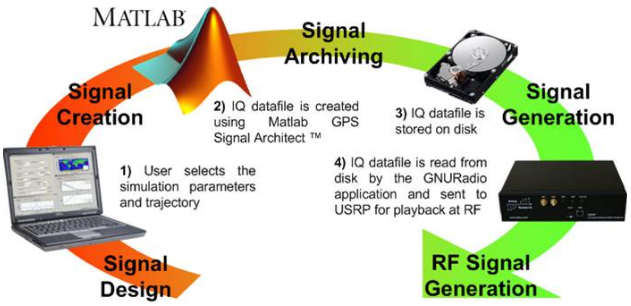

Figure 5 GNSS Signal Architect Test Set

As shown in Figure 6, this test setup can be used to record live GPS or interference environments for playback into a receiver under test. As described in the following section, the Signal Architect tools allow for this test setup to be used to inexpensively reproduce recorded or live GPS and interference signals for test and analysis of receiver performance in a lab environment.

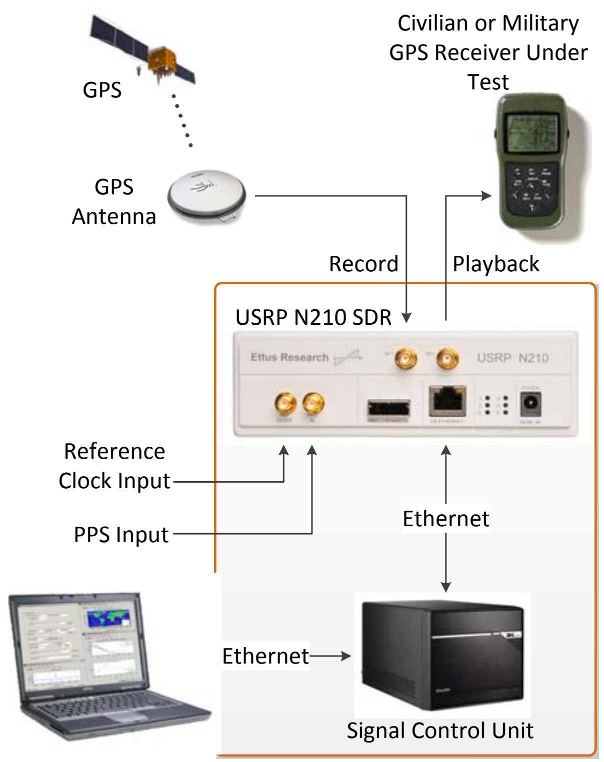

Figure 6 Interference Testing - Record and Playback

BROADBAND RECORD AND PLAYBACK

To reliably replicate the effect of interferers on a GPS receiver performance using digital signal playback, as illustrated in Figure 7, it is necessary to capture and remodulate signals using broader bandwidth and higher range Analog-to-Digital (A/D) levels than employed in the receiver under test. To perform capture of an interference environment, the GPS spectrum is captured over a 25 MHz bandwidth with a 16-bit A/D converter. A 1 terabyte removable drive is used to allow capture of up to three hours of data from a real environment into a DSF file. The Signal Architect tools also allow for generation of simulated interference signals into the same DSF format. The DSF File combiner tool can be used to add multiple DSF Files together from either simulated or recorded GPS and interference signals, adjust their relative power level and play these signals back into a receiver under test using a broadband software defined radio as an RF remodulator.

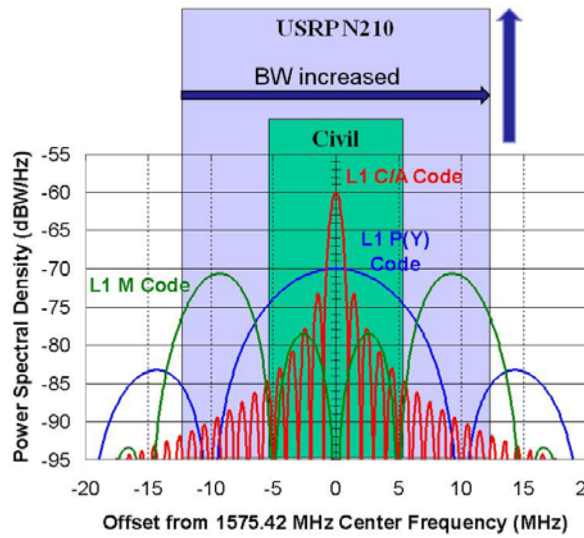

Figure 7 GPS Broadband Record and Playback

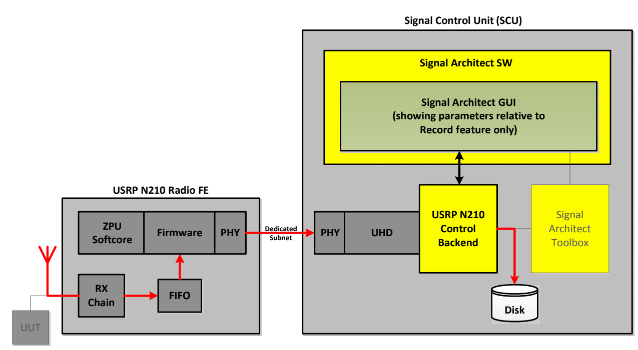

Figure 8 Broadband Signal Record and Playback Test Set

BROADBAND RF REMODULATOR

While the GNSS Signal Architect tools can be easily adapted for use with any commercial Software Defined Radio (SDR), Ettus was chosen due to their reasonable price, quality construction, and extensive support by the GNU Radio project[5]. Of the Ettus USRP family of radios, the N210[6] was chosen because it has the highest sample rate, greatest flexibility, and largest capacity for modification.

The USRP provides a standard Ethernet interface between high speed A/D converters and high speed digital-to-analog converters. Daughterboards, available for the USRP, provide an interface from the baseband signals present at the data converters to the GPS frequency bands.

For the broadband GPS interference testing, an Ettus WBX[7] transceiver daughterboard was installed in the USRP radio. The tunable range of the WBX (50 MHz to 2.2 GHz) covers all the current GNSS frequencies. The WBX allows up to 14 bits of data to be captured per channel.

The NAVSYS SDR Control Unit shown in Figure 8 includes a Linux SBC with software developed to run the GNU SDR for RF record and playback under control of the GNSS Signal Architect software through an Ethernet connection to a standard PC. The Ethernet connection is used to download and upload recorded or simulated signal files.

DSF FILE COMBINER

The DSF File combiner function allows for mixing and playback of a combination of live recorded and simulated GPS and interference signals, as illustrated in Figure 9. Broadband captured interference signals from live testing in a representative environment can be combined with either recorded live or simulated segments of the GPS signals and played back into GPS receivers under test. The relative signal/interference level can be adjusted through scaling the relative power of the GPS and interference DSF files before combining. Similarly, simulated segments of interference signals can also be combined with the GPS DSF files allowing testing under different simulated interference environments. The resulting DSF signal+interference files can be retained for comparison testing between receivers and also for qualification of performance. Any receiver manufacturer can perform testing using the same GPS+interference environment simply by receiving the appropriate set of DSF test files and using the low cost broadband signal playback capability in the Signal Architect test set.

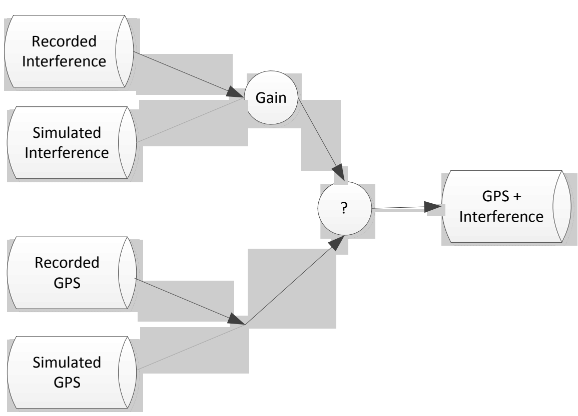

Figure 9 DSF File Combiner

GPS + INTERFERENCE TEST RESULTS

In June 2012, NAVSYS travelled to White Sands Missile Range to participate in the annual NAVFEST exercise held by the Air Force 746th Test Squadron, Central Inertial and GPS Test Facility (CIGTF). Anyone can attend this exercise with prior approval from the CIGTF, and it is a very valuable exercise. Held in the middle of the desert on approximately 500 square miles near Socorro, New Mexico, this exercise involves various interference producing devices, at various power levels, in pre-scheduled static and mobile scenarios on set frequencies bands. As an example, Figure 10 shows a normal signal spectrum without interference and Figure 11 shows the same signal spectrum with interference, both as recorded during this exercise.

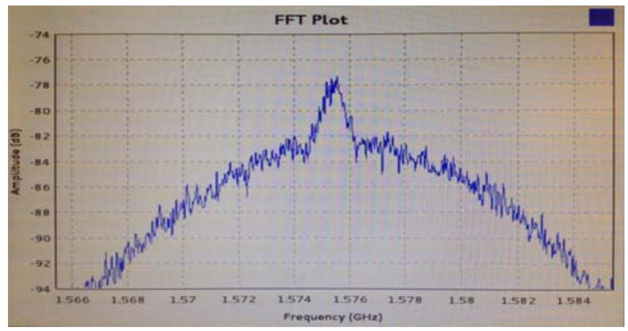

Figure 10 - Signal Spectrum without Interference

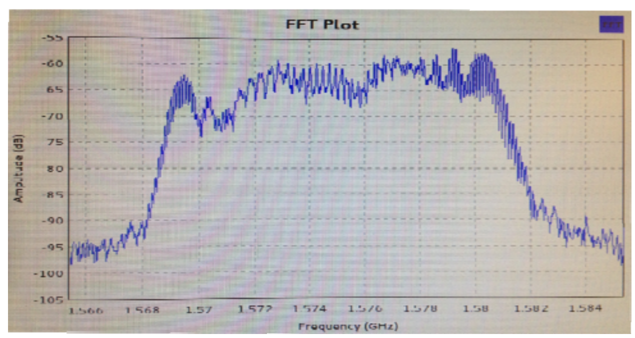

Figure 11 - Signal Spectrum with Interference

Naturally, holding such an exercise requires months of careful planning, travel to remote locations, specialized equipment, waivers and cooperation from multiple federal agencies, and the coordination of hundreds of people. In addition, to attend such an exercise requires multiple site visits by multiple personnel per organization, careful planning and equipment design, communications plans, coordination with many external agencies, and many man-hours of time in deploying and utilizing said equipment. In addition, there is no guarantee of success. For example, a last minute change in schedule, poor weather, or a simple equipment failure can result in a significant loss of opportunity.

As a result, gaining access to accurate and real-world interference data is vastly risky and expensive; and by corollary, the data successfully collected during such an exercise is inherently very valuable. Therefore, during this exercise, NAVSYS utilized our Signal Architect Test Set to record many terabytes of signal data for later processing and usage. This was done from various pre-determined static and mobile locations, at sample rates and resolutions at, or in excess of, the needs of our current projects, using high performance disk drives. In later analysis, the data can be resampled and rescaled to fit the needs of each given project and to reduce disk, memory, and CPU usage, as required. Additionally, sections of interest can be determined and extracted from this huge data set and extracted into individual portions that can be consistently and deterministically replayed into various systems as test vectors. This approach provides a rigorous and dependable test setup while drastically reducing the cost of performing interference testing across multiple projects and with different types of GPS receivers.

CONCLUSION

Using the NAVSYS Signal Architect Test Set enables record and playback of broadband GPS and interference signals into GPS receivers under test. By capturing live interference environments into DSF, post-test evaluations of a GPS receiver performance can be performed using data captured in a representative environment without requiring replication of the test environment in the field. Digital combining of the GPS and interference DSF files allows for adjustment of the relative signal/interference levels using either captured live or simulated signal environments. The use of digital playback into a broadband high fidelity RF remodulator avoids the need for expensive interference signal generator equipment or anechoic chambers to test GPS receivers. Also, one test can be played back from file into multiple receivers allowing comparative performance evaluations and saving costs by avoiding the need to travel to test sites to validate receiver performance under representative environments.

ACKNOWLEDGMENTS

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