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ITC 2019 Technical Program

Tuesday, October 22, 2019, 1:00 – 2:40 p.m. **Bronze 2**

Session 1 **Signal Processing**
Chair **Myron Moodie, Manager-R&D**
Southwest Research Institute (SwRI)

1:00 p.m.
19-01-01 **"Scalable Transmission and Decoding of Space Packets for Remote Satellite Image Browsing" 1**
Han Oh, Jae Young Chang, Jin-Hyung Kim & Hae-Jin Choi, Korea Aerospace Research Institute

The Consultative Committee for Space Data System (CCSDS) defines a standard for the data compression algorithm applied to the image data from payload instruments. In the CCSDS image data compression standard, an image is encoded using a three-level two-dimensional Discrete Wavelet Transform and the Bit-Plane Encoder. Compared to the JPEG2000 standard, the compression performance is reported to be similar at high bit rates with much lower complexity. However, its lack of highly scalable features supported by JPEG2000 hinders smooth browsing of the high-resolution satellite images. In this work, a method of quickly accessing a region of interest in a high-resolution satellite image is introduced. It utilizes parallel processing and the structure of the space packets which contain the strip-based code stream. This method is particularly effective for remote satellite image browsing and the study demonstrates its performance using KOMPSAT (Korea Multi-Purpose Satellite)-3A images.

1:20 P.M.
19-01-02 **"Alternate Method for Determining a TSPI Solution Based on TM Signal Strength" 9**
Scott C. Wolfson, US Army Redstone Test Center

The continual advances in military system technologies compel the Test & Evaluation community to constantly mature and adapt test methodologies and instrumentation capabilities. The need for alternate approaches aimed at collecting in-flight missile Time Space Position Information (TSPI) that compliment on-system high dynamic GPS and radar is just one example that supports the development of new techniques and numerical methods. The primary objective of the proposed presentation and subsequent technical paper is to provide conceptual details pertaining to a methodology that can determine a TSPI solution based on telemetry signal strength combined with the Newton-Raphson Jacobian method for solving a multivariate system of equations.

1:40 P.M. **"Three-Dimensional Motion Estimation and Image Formation with Active**
19-01-03 **Arrays" 16**
Vincent R. Radzicki & Hua Lee, University of California, Santa Barbara

For target imaging and tracking systems, a key signal processing task is motion estimation. Specifically, the trajectory of a maneuvering target undergoing rigid body motion can be described through a series of translational and rotational transformations. Estimation of these motion parameters provides the tracking system enough information to calculate the target's trajectory over time. Determining the rotational motion to a high accuracy is also very important, as the imaging system can then form an image of the target over multiple aspect angles and thus increase the resolution performance. This paper focuses on algorithm development and performance limitations for motion estimation and image formation using active sensing arrays.

2:00 p.m. **"Design and Applications of Probing Waveforms in Sensing and Imaging**
19-01-04 **Systems" 24**
Hua Lee & Vincent R. Radzicki, University of California, Santa Barbara

In active sensing, the probing waveforms play a profound role in the performance of a sensing system. This paper describes the concepts of the design and utilization of the probing waveforms and the associated signal processing algorithms in sensors and sensing systems. It governs both the computation complexity and accuracy of the estimation. It covers the evolution from the Green's functions in wave propagation to the use of wideband signals and then the chirp waveforms in time-delay estimation, displacement measurement, image reconstruction and the resolution in range and cross-range direction. In addition, the paper illustrates the structures of the estimation procedures, accuracy, limitations, and the tradeoff between resolution and computation complexity. The analysis then leads into the estimation of bearing angle for applications in direction finding and collision avoidance procedures.

2:20 p.m. **"A Novel FFT-Based Technique for Rapid Acquisition of High Dynamic**
19-01-05 **DSSS Signal" 36**
Wang Ming & Liang Taotao, Institute of Electronic Engineering, China Academy of Engineering Physics

A novel acquisition method for direct sequence spread spectrum (DSSS) signal of high dynamic surroundings is studied in this paper. The analysis result shows that the serial acquisition method cannot meet the requirements of high dynamic in-flight scenario, and it is necessary to acquire the capture possibility of correct signals in the case of low SNR and short acquisition time. For this purpose, the method with large doppler effects based on partial correlator and FFT is introduced. The proposed acquisition method is guaranteed to search the doppler

slot range according to the coherent integration time, and can calculate the C/A code phases simultaneously. In addition, the validity of this method by demonstrating that the simulation results are consistent with the experimental Scalable Transmission.

Tuesday, October 22, 2019, 1:00 – 2:20 p.m. Bronze 3

Session 2 **Software Defined & Cognitive Radio**
Chair **James Williams Yates, Vice President, Business Development, T&RF Products Space & Airborne Systems / L3Harris Technologies**

1:00 p.m. **"Channel and Spectrum Estimation for Software Defined Radio" 44**
19-02-01 Vincent R. Radzicki & Hua Lee, University of California, Santa Barbara

Software defined radios are rapidly increasing in both research and commercial usage for many different applications. As the number of deployed systems increase, a difficult problem that remains is efficient usage of the Radio-Frequency (RF) spectrum to be shared among all these devices. Two key tasks for the radio to perform here include spectral estimation of the RF environment and channel estimation of the communication channel for which the data will be transmitted. These two steps are linked as the communication channel can change over different portions of the RF-spectrum. In this work, an algorithmic approach is presented for passive and active channel estimation procedures for wideband software-defined radios. The algorithm is comprised of first channel quality estimation, followed by communication channel planning to optimize the overall performance.

1:20 p.m. **"Interference Mitigation of Adjacent Radio Frequency Signals On A Flexible**
19-02-02 **Software Defined Radio Testbed Platform" 51**
Mirza Elahi, Jose C. Sandoval & Virgilio Gonzalez, The University of Texas at El Paso; Pabel Corral & Susumu "Duke" Yasuda, ATEC WSMR

The radio frequency (RF) spectrum is crowded with users and adjacent frequency users are facing an increase in interference from each other. The spectrum governing body Federal Communications Commission (FCC) has the difficult task of allocating spectral bands for new users like 4G LTE and Telemetry (TM). To minimize the interference between adjacent frequency users, a common but inefficient method separates adjacent band frequencies using guard bands which leaves a big portion of the spectrum unused. Alternatively, adjacent RF signals can be separated using digital filtering techniques with the signal of interest being unharmed and reducing the signal power of the interfering signal. A digital filtering technique includes bandpass filter (BPF) rejection, where the passband and stopband frequencies are adjusted to achieve maximum signal power. A flexible software-defined radio (SDR) testbed is set up to experiment and analyze this scenario with ease and effective measures.

1:40 p.m. **"Classification Style Regression for Spectral Opening PMF Estimation" 66**
19-02-03 Garrett L. Fosdick & Michael Marefat, University of Arizona

Dynamic spectrum allocation (DSA) permits unlicensed users to access spectrum owned by a licensed user given they do so without interference to the primary user. To avoid interference with other users, the unlicensed user needs to be aware of channel availability. Spectrum sensing allows a radio to find spectrum holes, but costs energy and time. Predictive methods can be used to decrease the amount of spectrum sensing needed to find an available channel. We designed a novel neural network architecture for spectrum hole prediction. This neural network is capable of creating probability mass functions (PMF) estimates of the length of channel openings with no assumptions of the initial probability distribution or prior knowledge about the traffic. This architecture is shown to work through a mathematical proof, and its performance is measured through simulation.

2:00 p.m. **"Peak-to-Average Power Ratio (PAPR) Reduction for OFDM" 75**
19-02-04 Wondimu K. Zegeye, Farzad Moazzami & Richard Dean, Morgan State

The telemetry community has been challenged in its search for additional spectrum for its aeronautical mission. With a fixed amount of spectrum the challenge becomes focused on increased spectrum efficiency. Today's best solution for spectrum efficiency is Orthogonal Frequency Division Modulation (OFDM). This approach has proven effective with both cellular LTE as well as IEEE 802.11 wireless LAN systems. OFDM has seen limited use in telemetry systems in part due to issues related to high peak to average ratio of OFDM signals. This paper reviews approaches to resolving these issues and proposes a scheme for peak conditioning of OFDM signals to reduce the peak to average ratio. Results of preliminary experimental work are promising.

Tuesday, October 22, 2019, 1:00 – 2:20 p.m. Bronze 4

Session 3 Software Systems & Tools 1
Chair Timothy Brothers, Senior Research Engineer
Georgia Tech Research Institute, Electro-Optical Systems Laboratory

1:00 p.m. **"An Improved Log-Domain Belief Propagation Algorithm over Graphs with**
19-03-01 **Short Cycles" 85**
Nithin Raveendran, Shayan Garani & Bane Vasic, University of Arizona

We present a modified belief propagation algorithm (BP) for decoding low density parity check codes having graphs with short cycles. In this paper, we present the modified algorithm in log domain which is superior in terms of numerical stability, precision, computational complexity and ease of implementation when compared

to the algorithm in the probability domain. Simulation results show improvement in decoding performance for the modified BP compared to the original algorithm. The modified approach is also generalized for graphs with isolated cycles of arbitrary length by considering the statistical dependency among messages passed in such cycles.

1:20 p.m. **"NEURO-OSVETA: A Robust Watermarking of 3D Meshes" 95**
19-03-02 Bata Vasic, Nithin Raveendran & Bane Vasic, University of Arizona

Best and practical watermarking schemes for copyright protection of 3D meshes are required to be blind and robust to attacks and errors. In this paper, we present the latest developments in 3D blind watermarking with a special emphasis on our Ordered Statistics Vertex Extraction and Tracing Algorithm (OSVETA) algorithm and its improvements. OSVETA is based on a combination of quantization index modulation (QIM) and error correction coding using novel ways for judicial selection of mesh vertices which are stable under mesh simplification, and the technique we propose in this paper offers a systematic method for vertex selection based on neural networks replacing a heuristic approach in the OSVETA. The Neuro-OSVETA enables a more precise mesh geometry estimation and better curvature and topological feature estimation. These enhancements result in a more accurate identification of stable vertices resulting in significant reduction of deletion probability.

1:40 p.m. **"Using TENA and JMETC for Telemetry Applications" 105**
19-03-03 Gene Hudgins & Juana Secondine, TENA / JMETC

Often, TM requires operators on location with receive system(s) or at a remote console (with a remote antenna control unit), resulting in TDY for operators and possibly a shortage of operators to support all scheduled operations. A remote-control capability could eliminate existing personnel requirements at both the local system antenna site as well as the control facility, greatly reducing operational costs. TENA provides for real-time system interoperability, as well as interfacing existing range assets, C4ISR systems, and simulations; fostering reuse of range assets and future software systems. JMETC is a distributed, LVC capability using a hybrid network solution for all classifications and cyber. TENA and JMETC allow for the most efficient use of current and future TM range resources via range resource integration, critical to validate system performance in a highly cost-effective manner.

2:00 p.m. **"Designing a Telemetry System with a Focus on Education" 114**
19-03-04 Daniel Fuehrer & Michael Marcellin, The University of Arizona

The University of Arizona Baja Racing team competes in an international competition each year. We build a custom telemetry system for the car to collect data during races in order to inform design decisions and warn of upcoming problems. This paper will focus on the contrast between designing a system for production versus designing for the educational experience, as is the ultimate goal of our team. We will specifically discuss this contrast in the areas of size, power consumption, manufacturability, maintainability, repairability, and testability.

Tuesday, October 22, 2019, 1:00 – 2:40 p.m. Palace 3

*** Special Session 1** **iNET**

Chair **Thomas Grace**
NAVAIR

The Telemetry Network Standard (TmNS) (IRIG I06 Chapters 21-28) has been publicly released as IRIG I06-17 by the Range Commanders Council (RCC) Telemetry Group. This effort, started by CTEIP's iNET project, was launched to revolutionize telemetry across the DoD Ranges and Test Articles. These standards are a T&E force multiplier that provides flexible and secure bidirectional wireless IP networking capabilities that enable data delivery of multiple independent, concurrent flight tests. These standards are being utilized through various flight demonstrations and will be discussed. Ample time will be allocated for community questions and answers.

Tuesday, October 22, 2019, 3:30 – 5:10 p.m. Bronze 2

Session 4 **Channel Modeling & Synchronization**

Chair **Scott Kuijraoka, Senior Systems Engineer**
GBL Systems

3:30 p.m. **"CSI Estimation Using Artificial Neural Networks" 121**
19-04-01 Viraj Gajjar & Kurt Kosbar, Missouri S&T

We propose using machine learning to estimate channel state information (CSI) for MIMO communication links. The goal is to use information such as atmospheric conditions, amount of path loss, and Doppler shift to improve the accuracy of CSI

estimates. We start by designing an algorithm which estimates the CSI based on previously mentioned factors. Using this algorithm, we simulate a dataset of CSI over varying atmospheric conditions, receiver position, and receiver velocity. We then use this dataset to train an artificial neural network, which is able to estimate the CSI by using the current atmospheric condition, receiver position, and velocity.

3:50 p.m. 19-04-02 **"LDPC Coding for Frequency Diversity in Multichannel Air-to-Ground Telemetry" 131**

Mrugen A. Deshmukh & Stephen Wilson, University of Virginia

We consider the application of LDPC codes for improving performance in multi-channel (spectrum aggregation) for air-to-ground telemetry, by virtue of frequency diversity available on a wideband frequency-selective multipath channel. Each such channel is subject to frequency-selective fading over its bandwidth (typically a few MHz) due to multipath, for which standard OFDM equalization is standard. However, some subcarriers within this OFDM channel may experience deep fading at the output of the equalizer, rendering the symbol error probability poor relative to that on an AWGN channel. Specific performance reported will include uncoded symbol error performance as baseline, error rate of LDPC coding constrained to a single channel (diversity gain of order 3) and error rate of coding across eight channels (diversity gain of order 6). Further, performance on this dispersive fading channel is only about 3 dB worse than that on a no-multipath channel, at block error probability 0.01.

4:10 p.m. 19-04-03 **"Reinforcement Learning for Hybrid Beamforming in Millimeter Wave Systems" 138**

Ture Peken, Ravi Tandon & Tamal Bose, University of Arizona

The use of millimeter waves (mmWave) for next-generation cellular systems is promising due to the large bandwidth available in this band. Beamforming will likely be divided into RF and baseband domains, which is called hybrid beamforming. Precoders can be designed by using a predefined codebook or by choosing beamforming vectors arbitrarily in hybrid beamforming. The computational complexity of finding optimal precoders grows exponentially with the number of RF chains. In this paper, we develop a Q-learning (a form of reinforcement learning) based algorithm to find the precoders jointly. We analyze the complexity of the algorithm as a function of the number of iterations used in the training phase. We compare the spectral efficiency achieved with unconstrained precoding, exhaustive search, and another state-of-art algorithm. Results show that our algorithm provides better spectral efficiency than the state-of-art algorithm and has performance close to that of exhaustive search.

4:30 p.m. **"The Effects of Lossy Frequency-Domain EEG Compression on Cross-**
19-04-04 **Frequency Coupling Analysis" 148**
Andrew J. Phillips & Charles Creusere, New Mexico State University

This paper analyzes lossy frequency-domain compression in the context of cross-frequency coupling (CFC) analysis of electroencephalograph (EEG) signals. The approach used here for CFC analysis involves a low-complexity signal analysis block followed by a constant false alarm rate (CFAR) detection algorithm. The lossy frequency-domain compression is achieved via the threshold coding method for frequency truncation using the discrete cosine transform (DCT). This method is found to increase CFC detection rates by as much as 30% to 50% depending on the amount of Gaussian noise in the signal and the selected probability of false alarm. Further analysis indicates that these significant improvements in CFC detection rates are due to adaptive frequency-domain noise reduction. These results bode well for lossy frequency-based EEG compression schemes which can greatly improve transmission speeds and decrease storage space requirements while simultaneously enhancing CFC analysis capabilities.

4:50 p.m. **"Joint LTE Uplink Interference and Multipath Suppression for Aeronautical**
19-04-05 **Telemetry using MMSE Interference Canceler" 158**
Mohammad Saquib & Shamman Noor Shoudha, The University of Texas at Dallas

This paper addresses the use of a minimum-mean-square-error (MMSE) interference canceler for mitigating the Long-Term Evolution (LTE) uplink interference and multipath in Aeronautical Telemetry system. SOQPSK-TG modulation scheme for the telemetry victim signal and 64-QAM for the LTE interference signal are considered. For a multipath channel derived from the channel sounding data, the interference canceler achieves the target bit error rate (BER) of 1e-5 at Carrier-to-Interference (C/I) ratio -12.7, -40.7 and -36 dB for data rates 1, 5 and 10 Mbits/s, respectively. To offer the same performance, an MMSE channel equalizer requires C/I ratio -10.9, -25.0 and -5.0 dB.

Tuesday, October 22, 2019, 3:30 – 5:10 p.m. Bronze 3

Session 5 **Telemetry Networks 1**
Chair **Ken Wilhelm, Technical Lead Engineer**
The Boeing Company

3:30 p.m. **"JAMI and TENA - A Fusion of GPS and IP" 168**
19-05-01 Alvia Sandberg, Caleb Morse & Ryan Chandler, RTC

The Joint Advanced Missile Instrumentation (JAMI) project has created a very effective high dynamic Time Space Position Information (TSPI) solution and the Test and Training Enabling Architecture is a very effective way to share data over a network. Can JAMI and TENA work together? This paper answers that question.

3:50 p.m. **"Standardized Networked Telemetry Using Existing Cots Radio Modules" 173**
19-05-02 Ray O'Connell, RoboComAI

The T&E ranges require two-way networked communications to provide gains in critical areas including test efficiency, safety, cost savings and spectrum efficiency. The development of a network compatibility module which leverages networked telemetry standards while using existing COTS transmitter and receiver components has multiple benefits to the T&E test community. This component based approach to networked telemetry has the additional benefit of allowing new technology to be readily adopted for networking applications. This paper reviews the progress made in the development of a standardized component based networking telemetry capability as well as other networked telemetry radio systems.

4:10 p.m. **"Moving Towards 10 GbE Switches and Recorders" 181**
19-05-03 Russ Moore, Curtiss-Wright Defense Solutions

With flight test data acquisition and avionic bus data demands increasing every year, a new breed of network switches and recorders are needed to handle the new extreme data load to aggregate and record on solid-state media. Flight test instrumentation switches and recorders must perform in harsh environments with ultra-high levels of reliability. They must also facilitate fast and efficient movement and storage of data. Switches also require many features such as data aggregation, port-mirroring, and QoS (Quality-of-Service) support while recorder features such as port truncation, and support for PCAP, DARv3 & CH10 recording formats are important. This paper will discuss these needs and outline some use cases for new 10 GbE network switches and recorders.

4:30 p.m. **"Testing the Reliability and Flexibility of Digitizers Adapting the RF/IF**
19-05-04 **Signals Over IP Applications Using a Testbed Platform" 191**
Jose C. Sandoval, Virgilio Gonzalez & Mirza Elahi, The University of Texas at El Paso; Susumu "Duke" Yasuda & Pabel Corral, ATEC WSMR

RF Telemetry suffers many impairments in transmission systems that can now be eliminated using RF over IP Networks. Digitizers mitigate the problem of signal degradation that RF has due to physical restrictions and provide reliability and flexibility to the signal. The digitizers are also able to preserve both frequency and timing characteristics, and then accurately reconstructing the original Telemetry

signals to enable processing, recording or retransmission at another location. The digitizers along with the software-defined radios forms a flexible testbed platform which enables us to simulate both communication systems to qualify and quantify their behavior, while studying the interference between systems. In addition, quantization of noise is a critical parameter to determine the bit error rate in the testbed. Digitizers can be configured at a certain bandwidth and additional gain, in order to make this layer almost a transparent transmission.

4:50 p.m. **"Hybridization of Wireless Technologies for the Aerospace Instrumentation" 205**
19-05-05 François-Gabriel Percie du Sert, Ghislain Guerrero & Jean-Grégoire Ivanoff, Zodiac Data Systems

Whatever the flight test or space launch vehicle, the instrumentation presents strong intrusiveness due to the cabling. The industry is resolutely looking for a transition toward wireless architectures meeting its very specific constraints. The search has been oriented toward a single technology that could encompass all the needs. But there is a wide variety of use cases and associated requirements: data throughput, synchronization accuracy, power consumption, robustness of the link... No technology is able today to cover all these needs. Conversely, multiple technologies show specific characteristics that are optimized for some particular uses. Taking benefit of technologies' specific characteristics in a complex architecture is the way to go. Hybridization of wireless technologies will enable to address specific needs in a richer way to consider the wireless instrumentation, replacing today's architectures with no concession on performance.

Tuesday, October 22, 2019, 3:30 – 4:50 p.m. Bronze 4

Session 6 Antenna & RF Systems 1

Chair Tom Fisher, Technical Lead Engineer, Flight Test Radio
The Boeing Company

3:30 p.m. **"Resilient PNT/TSPI Alternative Solutions for Telemetry During GNSS**
19-06-01 **Outage Test Scenarios" 215**
Lisa Perdue & Sheri Ascencio, Orolia

GNSS is key to effective situational awareness providing critical Positioning, Navigation and Timing (PNT) telemetry data for mobile military operations. Yet the disruption of GNSS for increasing periods of time through jamming/spoofing is an essential test component in most test scenarios today. How can one still provide reliable Time-Space Position Information (TSPI) during periods of GNSS denial? This briefing will present key mobile military operations that rely on continuous and trusted PNT telemetry data from GNSS: •SatCom on the Move •C4ISR •Airborne Communications Relay •Synthetic Aperture Rada •Combat Search &

Rescue The same techniques used in these battlefield systems to provide alternative sources of PNT data during a GNSS outage can be used on the test range. Moreover, this briefing will also identify technologies, best practices and strategies for: •GNSS jamming/spoofing detection and protection systems •Testing protocols to maintain a state of PNT readiness

3:50 p.m. 19-06-02 **"An Approach for BER Determination Using Logged Aeronautical Telemetry Data" 225**
Souvik Sonar, Jimmy Tamakuwala & Avijit Jena, DRDO

BER, as a function of Eb/N0 is often used in prediction of ground telemetry systems performance for a mission configuration. However, there is no objective way of comparing the post flight results, as BER measurement in a flight test is not practically feasible for want of transmitting sufficient reference bit patterns. In this paper, an indirect way of computing BER and, in turn, link Eb/N0 is proposed for a PCM/FM link based on the frame synchronized data logged by the ground telemetry equipment. Using known quantities like bit rate and frame rate, a quantity defined as frame loss rate is computed. Applying the relations between frame loss probability, frame sync pattern and SFID information in the PCM format, an approach for bit error probability is demonstrated based on field data. By using a sliding window over a fixed length of data, BER for the entire flight duration can be determined as a function of flight time with the step size of the length of data window.

4:10 p.m. 19-06-03 **"Dual-Channel Receiver Performance Using Best-Channel Selection: Field Test Results" 234**
James Uetrecht, Quasonix

Best-Channel Selection (BCS) uses real-time data quality metrics (DQM) to select the best demodulated bits from Channel 1, Channel 2, and the Combiner of dual-channel receivers. Laboratory testing has demonstrated a substantial reduction in bit error rate (BER) relative to individual channels (including the Combiner) under some synthesized link conditions, with no degradation in BER under the remainder of tested link conditions. This paper extends those results to real-world flight tests.

4:30 p.m. 19-06-04 **"Co-existence of Aeronautical Mobile Telemetry and LTE Systems in the S- Band" 244**
Mohammad Saquib & Shamman Noor Shoudha, The University of Texas at Dallas

This paper analyzes the effect of Long-Term Evolution (LTE) uplink interference on the performance of Aeronautical Telemetry S-band users. A MATLAB simulation environment is used to analyze the interference effect using SOQPSK-

TG and 64-QAM modulation schemes for telemetry and LTE transmitters, respectively. An ideal Surface Acoustic Wave (SAW) filter followed by a 2-by-2 symbol detector is used in the telemetry receiver. To ensure a target bit error rate (BER) of 1e-5, depending on the LTE spectrum mask, the Carrier-to-Interference (C/I) ratio requirement is -15.4, -32.4 and -30 dB for data rates 1, 5 and 10 Mbits/s, respectively.

4:50 p.m. **"Test Methods and Results for Adaptive Equalizers" 253**
19-06-05 Terry Hill, Quasonix

Multipath distortion has been a major source of data corruption in aeronautical telemetry signals for decades. In recent years, however, adaptive equalizers have begun to appear in telemetry receivers. These equalizers offer the promise of mitigating or even eliminating the damage done by the multipath channel, and many ranges are adopting their use. Unfortunately, there have not been any standardized tests by which to quantify the efficacy and limitations of adaptive equalizers. This paper presents a generalized test methodology for making a quantitative performance assessment of any adaptive equalizer, along with representative test results for one particular adaptive equalizer.

Wednesday, October 23, 2019, 10:30 – 11:30 a.m. Bronze 2

Session 7 Security

Chair Brian Keating, Head, Aircraft Instrumentation Division
NAVAIR-NAWCAD

10:30 a.m. **"Cyberdefense and Data Security in Flight Test Applications" 263**
19-07-01 Malcolm Weir, Ampex Data Systems Corp

Specialist test establishments have historically placed significant reliance on "security through obscurity". With increasing "always on" connectivity and the drive to leverage commercial products, the threat space has widened significantly while the sophistication of attack vectors has evolved. Access through vulnerabilities embedded within a platform's communications, flight controls, or other on-board access points leave organizations vulnerable to attack, exploitation, and loss of revenue or property. Cyber and operational security associated with all aspects of aircraft technologies is becoming increasingly critical. This paper investigates techniques and procedures by which aircraft and space vehicles can be compromised by and protected against cyber-attacks.

10:50 a.m. **"Multi-Stage Attack Detection Using Layered Hidden Markov Model**
19-07-02 **Intrusion Detection System" 273**
Wondimu K. Zegeye, Farzad Moazzami & Richard Dean, Morgan State

Intrusion Detection Systems (IDS) based on Artificial Intelligence can be deployed to protect telemetry networks against intruders. As security solutions which encrypt radio links do not accommodate the ever-evolving network attacks and vulnerabilities, new defense mechanisms using machine learning and artificial intelligence can play a significant role for telemetry networks. This paper proposes a multi-layered Hidden Markov Model (HMM) IDS that addresses multi-stage attacks. This is due to the fact that intrusions are increasingly being launched through multiple phases instead of single stage intrusion. This layered model divides the problem space into smaller manageable pieces reducing the curse of dimensionality associated with HMMs. To verify the application of this model for real network, the NSL-KDD dataset is used to train and test the model.

11:10 a.m.
19-07-03 **"Augmenting Cybersecurity in Telemetry Post Processing Environments with Insider Threat Analysis" 283**
Jeff Kalibjian, Perspecta

Mature companies implement robust cybersecurity practice in their organizations by deploying a layered defense comprising many differing security tools whose functionality complements one another. Tools such as firewalls, Anti-Virus (AV), Intrusion Detection/Prevention (IDS/IPS), Data Leak Protection (DLP), and Security Information and Event Management (SIEM) can be rolled out in many combinations to create very effective cyber defenses. A general premise is that organizations are trying to keep "bad guys" out! In recent years, focus has been shifting to address the potential for malicious (insider) employees who may wish to take actions to compromise the firms they work for as an increasing number of incidents are attributed to insiders. After reviewing the insider threat landscape as well as accepted methodologies for detection; application to telemetry post processing environments will be discussed with example deployment scenarios explored.

Wednesday, October 23, 2019, 10:30 – 11:30 a.m. Bronze 3

Session 8 **Telemetry Networks 2**
Chair **Doug Bell, Instrumentation and Data Systems Engineer**
The Boeing Company

10:30 a.m.
19-08-01 **"Lessons Learned During the Introduction of Network / IP Telemetry in Flight Test Instrumentation for Helicopters" 290**
Renaud Urli & Florian Mertl, Airbus Helicopters

Flight Test Instrumentation architectures are nowadays based on network topologies. However, the telemetry link has kept the legacy PCM technology for most applications. By implementing network / IP radios, the drawbacks of old

fashioned PCM-based telemetry links could be eliminated. Furthermore, new use cases have become possible, and the architecture of FTI installations, both on board and on ground, could be simplified. This paper gives some technical background on networked / IP radios and describes the steps taken during the first introduction of this promising technology. The benefits of this system are explained in order to show the potential of that approach. Beside this, important lessons were learned during the introduction of the network / IP telemetry: from software to hardware topics, from topology to human factors aspects. Eventually, the present installation at the FTI facility is described as well as the status of the migration from S-band PCM/FM to IP C-Band.

10:50 a.m. **"Investigation into the Development of a Wireless IoT Penetration Testbed" 296**
19-08-02 Tellrell White & Willie Thompson, Morgan State University

IoT protocols have been proposed to replace wired systems in aircraft to support telemetry applications. They offer several advantages to wired systems due to them being wireless, low cost, and consuming less power. However, the one consideration that is often overlooked is the security of these wireless protocols. This project focused on investigating the use of open source hardware and software frameworks to create a wireless testbed to conduct penetration testing of the ZigBee protocol. To accomplish this task, the open source XBee software library was used to implement the ZigBee Network and Application Layers within the GNU Radio IDE. The XBee hardware module was leveraged for the IEEE 802.15.4 PHY and MAC Layers.

11:10 a.m. **"Direct Implementation of a Bidirectional Network Communication Link in**
19-08-03 **Civil Aircraft Flight Test Using Modified LTE Air-to-Ground System" 304**
Xianyu Du & Guobao Deng, COMAC Flight Test Center

This paper mainly describes a preliminary trial implementation of a bidirectional network communication link for aircraft range flight test application based on modified LTE Air-to-Ground systems. The theoretical feasibility of this trial which integrated the existing on-board network-based acquisition system installed on our regional jet and a newly designed modified LTE Air-to-Ground communication system was carefully analyzed and validated before system level ground experiments. Finally, several test flights were performed within a specific airspace with two eNodeBs, which configured as an independent LTE network and covered most of the designed flight path, and the test results give us the conclusion that under the promise of deploying reliable ground base stations, LTE system has the potential capability to provide acceptable bandwidth and time delay performance for range flight test application.

Wednesday, October 23, 2019, 10:30 a.m. – 12:10 p.m. Bronze 4

Session 9 **Antenna & RF Systems 2**
Chair **Jim Falasco, Sales Engineer**
AeroGear Telemetry

10:30 a.m. **"An All-Digital Antenna Control Protocol" 310**
19-09-01 James Uetrecht, Quasonix

For decades, analog amplitude modulation (AM) imparted by antenna feeds has served as the gold standard by which antenna control units (ACUs) manage tracking. This paper presents a digital alternative, designed to provide AM information, signal quality metrics, and additional real-time status, all over existing analog AM cables. Its benefits include reduced (and known) delay in the tracking loop, smart selection among multiple tracking receivers, and support for advanced features such as tracking through interfering signals and tracking intermittent or time-division-multiplexed transmissions.

10:50 a.m. **"Mitigation of Antenna Polarization Transformations Caused by Airframe**
19-09-02 **Reflections" 316**
Marwan Nusair & Mark S. Geoghegan, Quasonix

The majority of aircraft telemetry antennas transmit a linearly polarized wave. These linearly polarized signals are often received by two orthogonal (left and right hand) circularly polarized receive antennas, each of which has 3 dB polarization loss. Under nominal conditions, a diversity combiner can be used to coherently add the two received signals, thereby restoring the 3 dB loss. Recent flight tests have revealed that the signals radiating from the aircraft are actually elliptically polarized or even circularly polarized, leading to degraded combiner performance. This paper describes how the transmit polarization can be transformed from linear to circular, why this degrades combiner performance, and how to mitigate this effect.

11:10 a.m. **"Effect of Rotating Propellers on Telemetry Signals" 326**
19-09-03 Marwan Nusair & Mark S. Geoghegan, Quasonix

The migration of aeronautical telemetry systems to C band has prompted a fresh look at many historically uninteresting facets of telemetry links. The effects of higher cable losses and smaller antenna beamwidths, for example, have been recognized and accounted for. Recent flight tests at Edwards AFB with a propeller-driven aircraft have revealed another such effect, which we have termed "prop chop". Realtime data quality metric (DQM) values showed a periodic fluctuation in DQM, related to the aircraft engine speed. An investigation of this phenomenon

using detailed electromagnetic simulation of a transmit antenna in the presence of a propeller shows a mechanism for this interference, both when the propeller is in front of the transmit antenna and when it is behind the transmit antenna. This paper compares the electromagnetic propagation simulation results to measured values from the field.

11:30 a.m. 19-09-04 **"Upgrading to Best Source Selection: A Look at the Architecture Required to Make It Work" 336**
Grant Gerstner, NAVAIR

A comprehensive guide to implementing best source selection at a test range. This paper uses the history of the Atlantic Test Range's implementation as a guide to show the steps needed to implement Best source selection. It also discusses the advantages to best source selection at all levels of implementation.

11:50 a.m. 19-09-05 **"Adaptive OFDM for Aeronautical Channels" 347**
Wondimu K. Zegeye, Farzad Moazzami, Richard Dean & Tasmeer Alam, Morgan State University

Previous work modeled the cruise phase of an aeronautical channel and showed how the channel varied as a function of height, distance, and speed. What was apparent from that analysis was that the ``cruise'' channel was remarkable stable and varied slowly and predictably over time. The steady state channel reflected a 2-ray multipath model which exhibits deep nulls in the spectrum which affects serial tone modems significantly. Further the application of parallel tone modulation improves performance except for that portion of the band which was degraded by the null. This points to the use of Adaptive OFDM (AOFDM) structure wherein tones are only sent in portions of the band which are strong and not areas where the signal is weak. This work develops a method for capturing a profile of the Signal to Distortion Ratio (SDR) for each tone for each frame and over time. It also converts the SDR per tone to estimate the optimum QAM modulation scheme for each tone for application in LDAR.

Wednesday, October 23, 2019, 10:30 a.m. – 12:00 p.m. Palace 3

*** Special Session 2** **"International Threats to Telemetry Spectrum for 2019" *(hosted by the ICTS)***

Chair **Guy Williams, Air Force Test Center**

This special session, sponsored by the IFT's International Consortium for Telemetry Spectrum (www.telemetryspectrum.org), will cover potential threats to the life-blood of telemetry; RF Spectrum. Telemetry professionals, providers, and

customers should monitor these threats closely and take action as needed to ensure that the needs of the greater telemetering community are reflected in international and domestic regulations and policy.

Wednesday, October 23, 2019, 2:00-4:00 p.m. Bronze 4

Session 10 Sensors & Data Acquisition
Chair Jon Morgan, Computer Scientist V
JT4, LLC, 412th Test Wing, Edwards AFB

2:00 p.m. **"Developing Wireless IMUs to Simplify Integration into Dynamic Systems" 356**
19-10-01 Jacob Lipina, Austin Christman, Rebecca Marcolina & Kurt Kosbar, Missouri S&T

This paper discusses the development of wireless inertial measurement units (IMUs) designed to transmit data from a prototype Mars rover to a remote base station. These nine degrees of freedom, multi-chip modules provide measurements for linear acceleration, angular rotation velocity, and magnetic field vectors for the rover's chassis and robotic arm end-effector. To facilitate integration into these dynamic systems, each unit is independently powered and has a form factor of 108 cc. IMU data is sent from 32-bit microcontrollers with embedded IEEE 802.11 b/g/n Wi-Fi to the rover via UDP transport through a custom publish/subscribe distributed IP protocol. Data is relayed over two circular polarized omnidirectional antennas to the base station's dual linear MIMO Yagi-Uda antenna. The information gathered provides operators a heading and orientation to improve situational awareness, as camera visuals are often inadequate.

2:20 p.m. **"Monitoring Stress and Vibrations on Amusement Park Rides" 365**
19-10-02 Chad George, Tierny Rubenow, Zane Craddock, Tiffany Ma, Anthony Collett & Gerardo Garcia, University of Arizona

On amusement park rides, vibrations against the rails of the track and the cars' wheels can strain and damage the track. This is especially true for older coasters, whose tracks have worn significantly over time. While manual inspection of the track is necessary, an automated system that monitors the stress on the track will help detect anomalies, ensuring a safe experience for the passengers. We have designed a system of sensors that can monitor these vibrations. Sensors placed on a segment of track will measure the lateral and vertical vibrations, wirelessly transmitting the level of strain on the track to a base station. If vibrations reach a threshold level, the base station will be alerted of excessive strain. The system will create a graph of points where vibration is worse than other points, to pinpoint what areas need the be fixed the most. This will decrease maintenance costs and ensure increased safety for patrons of these rides.

2:40 p.m. **"Optimizing Pre-Flight Checkout by Leveraging IOT Enabled FTI and**
19-10-03 **Augmented Reality" 372**
Patrick Quinn, Curtiss-Wright Defense Solutions

Pre-flight checkout is one of the most time critical stages in any flight test program. Delays and in-efficiencies during checkout can lead to aircraft being grounded for unnecessarily long periods of time, increasing costs and program schedule slippages. This paper describes how pre-flight checkout can be optimized by combining best in class Internet of Things (IOT) enabled Flight Test Instrumentation (FTI) and augmented reality wearables. With the dawn of augmented reality wearables, smart sensors, wireless sensors and next generation FTI, today's technological advances can be leveraged to transform pre-flight checkout into an interactive, self-diagnostic and operationally efficient essential step in your flight test program. These same technologies can also be used to optimize the day to day operations of airlines, and MRO companies, taking advantage of the current 'data rich' generation of aircraft.

3:00 p.m. **"Vibration Analysis with an Optical Tracking System (SisTro)" 377**
19-10-04 Andre Kusumoto & Nelson Leite, IPEV; Luiz Eduardo G. Vasconcelos, ITA/IPEV/INPE; Carlos Lahoz, ITA

The development and validation of the Sistema de Trajetografia Ótico (SisTro - Optical Tracking System), to be used for external store separation flight test, required the execution of several Pit Drop tests. The accurate determination of the store trajectory in real time by SisTrO, expressed in 6DoF, used computed vision techniques for photogrammetric measurements and a novel optical error minimization process. 2D image tracking of the in-view reference points could be determined with sub-pixel resolution, that allowed us to measure the aircraft vibrations. Such novel capability allows us to develop a more accurate Computational Fluid Dynamics (CFD) simulation models by the incorporation of the aircraft Flexible-Body Mechanics model into such simulation runs. In this paper it will be presented the development of SisTrO sub-pixel tracking process and the pit drop test results, that includes the measurement of the wing and pylon vibrations and its damping factor.

3:20 p.m. **"Autonomous and Non-Intrusive System for Enhanced Space Vehicle**
19-10-05 **Location" 387**
François-Gabriel Percie du Sert & Adolfo Escudero, Zodiac Data Systems

High-precision location of space launch vehicles is a key component of the flight safety. The need for a very accurate location has gained the whole launch with the flight and re-entry stages being also critical in terms of safety. Thanks to the hybridization of GNSS and INS data, the accurate location can be fully defined inside the launch vehicle at low cost. This opens up to the setting of an autonomous system for location on-board the vehicle. Still, in order to ensure the reliability of

such a system, many redundancies have to be set which implies to add equipment: autonomous power, processing, unique telemetry downlink… Adding this equipment challenging in an environment where the use of room and the adding of weight are very tightly monitored. This paper describes the techniques to settle a fully autonomous location system which answers to the needs for an accurate, strongly reliable location while being non-intrusive, cost-effective and easily integrated in any launch vehicle.

3:40 p.m.
19-10-06

"A Novel Combining Acquisition Algorithm with Data and Pilot Signals of BDS-3 B1C Signal" 397

Liang Taotao & Wang Ming, Institute of Electronic Engineering, China Academy of Engineering Physics

A novel power-weighted combining acquisition algorithm of B1C signal, which can be applied in high dynamic scenario, is developed in this paper. B1C signal is the primary signal of the Third-generation BeiDou Navigation Satellite. The B1C signal adopts a new navigation signal system including pilot and data signal. These two signals are transmitted simultaneously in an orthogonal manner. When the signal is weak, two signals need to be processed jointly to improve the signal detection ability. This paper designs a novel weighted joint acquisition algorithm. Monte Carlo simulation has been done to evaluate the performance. The simulation results show that the detection performance of the proposed algorithm connects with the weighted coefficient. When the optimal weighting coefficient is selected, detection performance can be improved greatly under the condition of weak signal.

Wednesday, October 23, 2019, 2:00-4:20 p.m. Bronze 2

Session 11 **RF Spectrum**

Chair **Mark McWhorter, V.P. of Sales & Marketing**
Lumistar, Inc

2:00 p.m.
19-11-01

"Development of Network Data Aggregator for Payload Filtering to Control Telemetry Bandwidth" 405

Charles Reyzer, Philip Ellerbrock & Robert Zettwoch, Boeing; Andy Kragick & Troy Troshynski, Avionics Interface Technologies

Emerging aircraft avionics and vehicle management communication systems have switched to higher data rate networks such as Ethernet and Fibre Channel, requiring Flight Test systems that can acquire data information from these networks. The data has moved onto higher speed networks, but the telemetry bandwidth has not increased, therefore producing a need to selectively capture data from within a packet, down to the bit level, for telemetry without requiring to capture the entire message. Ethernet and Fibre Channel are transport protocols

without rigid payload structure definitions such as MIL-STD-1553 or ARINC-429. Avionics traffic can be defined in any manner including dynamic length components or repeating structures that are difficult to define generically. AIT (Avionics Interface Technologies) developed the Airborne Network Data Aggregator (ANDA) unit for The Boeing Company with six different payload structure filter types to generically capture data out of network structures.

2:20 p.m. **"Effects of Swarm Density on Multihop Drone Telemetry Data" 415**
19-11-02 Justin P. Rohrer, Naval Postgraduate School

Bandwidth being a limited resource in airborne telemetry networks, drone swarms are particularly challenging to instrument due to the number of airborne nodes involved. Even a modest amount of data being transmitted by each node may overwhelm the network. Prior work has evaluated these effects in a number of drone swarm mobility scenarios and shown the difficulty of achieving reliable data delivery. However, those results do not distinguish between data loss due to congestion of the available spectrum, and loss due to changing network topologies or disconnection due to mobility. In this work we attempt to isolate those effects by keeping a simulated drone swarm stationary and focusing on the telemetry data delivery due to changing the size and density of the swarm. We compare the performance using no multi-hop routing protocol, as well as using DSDV, AODV, DSR, and OLSR.

2:40 p.m. **"Verification Techniques for Spectrum Usage in Space, Time and**
19-11-03 **Frequency" 423**
Phiroz H. Madon, Perspecta Labs Inc.

A Spectrum Usage Measurement System (SUMS) characterizes the actual use of telemetry spectrum at DoD flight test ranges. The system tracks daily usage in a measurements repository, which becomes an invaluable resource, allowing querying, reporting and analytics, for defending against future spectrum sell-offs, and for providing insights into improving spectrum efficiency. The question is how do we quantify spectrum usage in space, time and frequency? And how do we certify "actual usage", as opposed to simple allocation and claims that the spectrum was planned to be used? We discuss techniques for addressing these challenges. The system draws upon spectrum mission planning data, a network of sensors of various types, and a correlation algorithm. A scaling problem characterizing the spatial extent of the spectrum usage is solved. Correlation, using heterogeneous data sources at a test range with numerous RF emissions prompts a heuristics and flexible rules-based approach.

3:00 p.m. **"Block Generalized Spatial Modulation for Massive MIMO Systems" 433**
19-11-04 Elam A. Curry & Deva Borah, New Mexico State University

Spatial modulation techniques have the ability to convey information by both the positions of active antennas as well as the symbols they transmit. Such techniques include the generalized spatial modulation (GSM) that can provide high spectral efficiency. In general, however, the total number of available symbols in GSM is not a power of two. Therefore, selection of a symbol alphabet from the available symbols is needed. This is a numerically complex problem. In this paper, we propose to significantly reduce the complexity of the GSM symbol set selection problem by grouping antennas together to form blocks, thus producing block GSM (BGSM) symbols. A previously developed iterative combinatorial method is extended to BGSM symbol selection. The effects of the Rician K-factor, BGSM symbol block size, and antenna configuration on the performance and design complexity are studied. The algorithm is found to significantly reduce the complexity of the BGSM symbol set selection problem.

3:20 p.m. 19-11-05 **"On Carrier Frequency and Phase Synchronization for Coded 16-APSK in Aeronautical Mobile Telemetry" 443**

Michael Rice, Bryan Redd & Ximena Briceno, Brigham Young University

This paper examines the problem of carrier phase and frequency estimation for coded 16-APSK in aeronautical mobile telemetry. Given the fact that coded systems tend to operate at lower signal-to-noise ratios than uncoded systems, the synchronizer must operate at these lower signal-to-noise ratios. For a 30 kHz frequency offset and a 10 Mbit/s 16-APSK signal, the conventional phase lock loop (PLL) system does not achieve consistent lock to be a useful approach. Blind feedforward FFT-based estimators and feedforward-initialized PLLs can achieve good performance.

3:40 p.m. 19-11-06 **"Polarization Diversity and Equalization Of Frequency Selective Channels In Telemetry Environment For 16APSK" 456**

Farah Arabian & Michael Rice, Brigham Young University

Providing RHCP and LHCP outputs from the antennas vertical (V) and horizontal (H) dipoles in the resonant cavity within the antenna feeds is the current practice of ground-based station receivers in aeronautical telemetry. The equalizers on the market, operate on either LHCP or RHCP alone, or a combined signal created by co-phasing and adding the RHCP and LHCP outputs. In this paper, we show how to optimally combine the V and H dipole outputs and demonstrate that an equalizer operating on this optimally combined signal outperforms an equalizer operating on the RHCP, LHCP, or the combined signals. Finally, we show how to optimally combine the RHCP and LHCP outputs for equalization, where this optimal combination performs as good as the optimally combined V and H signals.

4:00 p.m. **"DFT-based Frequency Offset Estimators for 16-APSK" 468**
19-11-07 Bryan Redd, Jamison Ebert, Autumn Twitchell & Rice, Brigham Young University

In this paper, we analyze several DFT-based frequency offset estimators for use with the 16-APSK digital modulation scheme. Even a small frequency offset between radio transmitters and receivers can cause phase information to be lost, so a system to align the phases is required to reliably demodulate PSK signals. These estimators have been adapted for 16-APSK from methods originally intended for use with QPSK and CPM. These methods consist of a coarse search and a fine search with an optional dichotomous search to improve accuracy. We analyze the estimator error variance and bit error rate associated with several methods of frequency estimation. These estimators exhibit small estimate error and variance and can provide bit error rates close to the ideal AWGN BER.

Wednesday, October 23, 2019, 2:00-4:20 p.m. Bronze 3

Session 12 Selected Topics

Chair Mark Smedley
NAVAIR

2:00 p.m. **"CCDC-AC High Spin Artillery OBR" 479**
19-12-01 Alfred Rotundo, Army: CCDC-AC

Developed an on-board-recorder (OBR) to capture both in-bore acceleration and in-flight canister expulsion forces for an artillery projectile. The instrumentation recorded on the OBR was fed into a model to simulate these forces. The OBR's space claim was limited to the expulsion cavity of the artillery projectile. The OBR was equipped with an analog sensor suite that recorded battery, expulsion pressure, high-g in-bore axial accelerometer data, and radial spin data. Utilizing 8 channels of the ADC on the DSP, the sensors are recorded into both volatile SRAM and NOR Flash memory. The OBR matched both weight and center of gravity of the tactical artillery round. To accomplish this, multiple housing materials and potting materials were utilized. The OBR survived multiple shots. The OBR was instrumented successfully on 4 rounds, allowing an accurate model and simulation to be created to increase design reliability and minimize failures on future designs.

2:20 p.m. **"Teleoperated Robotic Arms with Open and Closed Loop Control Systems" 489**
19-12-02 Eli Verbrugge, Brian Dahlman & Kurt Kosbar, Missouri S&T

This paper examines the usage of telemetry for the six degree of freedom robotic arm designed to compete on a Mars rover in the 2019 University Rover Challenge. The arm utilizes three microcontrollers to receive control commands and translates them directly to motor signals for the six brushless DC motors. The usage of the 32-bit microcontrollers facilitates inverse kinematics, an intuitive process that allows commands to be sent as 3D coordinates to the arm, ensuring fine control for arm manipulation. Telemetry will be transmitted from the rover to a remote base station over a 900 MHz band using two omnidirectional cloverleaf antennas. Communication between the embedded systems is achieved with the ethernet User Datagram Protocol standard. This ensures seamless transferal of commands from the driver's joystick to the arm, and a stream of telemetry containing motor currents, positional values, and limit switch states - a necessity for the open and closed loop control systems.

2:40 p.m. **"Software Conversion of Legacy Recording Format to IRIG 106 Chapter 10**
19-12-03 **File" 499**
Richard A. Graham, US Navy

This paper examines how to convert files recorded on a legacy recorder to an IRIG 106 Chapter 10 file.

3:00 p.m. **"Remote Heart Monitoring via Medical Telemetry" 505**
19-12-04 Vincent R. Radzicki & Hua Lee, University of California, Santa Barbara

Today, a wide range of heart conditions can be monitored remotely with relatively inexpensive passive sensing technologies, enabling the potential for long-term monitoring and prognosis of patient state under representative environmental stimuli. A medical telemetry system that can incorporate such passive measurements and provide key diagnostic information to medical professionals would provide tremendous value to patients via quantitative and personalized healthcare. This paper presents an overview of passive sensing methods that could be utilized in a medical telemetry system for remote heart monitoring of patients. While active systems are another attractive option, they impose additional constraints on the system that require careful calibration, expert control, and more complex instrumentation. The methods presented here are based on low-cost, sensor technology with the potential to greatly improve long-term non-invasive, heart-healthy monitoring.

3:20 p.m. **"Telemetry on Wildcat Formula Racing Vehicle" 515**
19-12-05 Nicolas J. Tan & Michael Marcellin, The University of Arizona

The electronics team of Wildcat Formula racing of the University of Arizona is currently developing the data acquisition and telemetry system for the Formula Society of Automotive Engineers 2019 Competition in Lincoln this summer. We use a mixture of automotive sensors and Arduino sensors to be transmitted to the ECU and will be extracting the said data from the ECU onto the Arduino through the CAN BUS protocol. The data will then be stored locally and broadcasted from the vehicle to the pit. The data will be processed for post-race data analysis and provide live information to the driver.

3:40 p.m. **"Decorrelation Deep Learning for Fingerprint-Based Indoor Localization" 520**
19-12-06 Xiong Guojun, Kim Taejoon & Erik Perrins, University of Kansas

The sensitivity of the indoor localization performance to channel fluctuation is a drawback. To address this challenge, we adopt an artificial multi-layer neural network (MNN) to learn the complex channel impulse responses (CIRs) as fingerprint measurements. However, the performance of the location classification using MNN critically depends on the correlation among the training data. Therefore, we design two different decorrelation filters that preprocess the training data for discriminative learning. The first one is a linear whitening filter combined with the principal component analysis (PCA), which forces the covariance matrix of different feature dimensions to be identity. The other filter is a nonlinear quantizer that is optimized to minimize the distortion incurred by the quantization. Numerical results using indoor channel models illustrate the significant improvement of the proposed decorrelation MNN compared to other benchmarks.

4:00 p.m. **"LIDAR Collision Avoidance System with Audio Feedback For The Visually**
19-12-07 **Impaired" 530**
Julian A. Maravilla & Hua Lee, University of California, Santa Barbara

In this paper, we present two 4th-generation light-weight low-power collision avoidance systems. For this new version, the ultrasound transmitter of the data-acquisition component is replaced by a Lidar to avoid multi-paths in complex environment. The estimate of the target range is quantized into a frequency bin and represented by acoustic waveforms within the human hearing range. The bearing angle of the target is utilized to produce the temporal offset between the twin channels of the corresponding acoustic waveforms. This set of wearable-hearable devices is designed for real-time navigation for the visually impaired.

Wednesday, October 23, 2019, 2:00-3:20 p.m. Bronze 1

Session 13 Modulation & Coding

Chair **Tim Gatton, Sales Engineer**
AeroGear Telemetry

2:00 p.m. **"An Engineer's Guide to Chapter 7 Packet Telemetry Transport" 539**
19-13-01 Richard W. Hoffman, GDP Space Systems

Chapter 7 of IRIG106-17 defines the means of encapsulating packetized data within a PCM telemetry stream, ostensibly for transport from a platform to a processing location, via that platform's conventional means of PCM transmission. While providing a mechanism for bridging platforms via the telemetry stream, a myriad of use-cases evolves, adding varying degrees of complexity to an implementation. Understanding these use-cases, their challenges, and some of the potential solution methodologies helps to determine the best implementation for a given mission. This paper seeks to present some of these aforementioned points, some obvious, and others uncovered over the course of working with solutions-seekers, in an effort to help cultivate and shape the growing demand for packet telemetry transport bridging.

2:20 p.m. **"An Introduction to IRIG-106-17 Features and Associated Command**
19-13-02 **Structures" 548**
Paul Cook, Curtiss-Wright Defense Solutions

The RCC Telemetry group publishes various documents and IRIG-106 aims to standardize telemetry solutions. Such efforts help to ensure that ranges – and other flight test users – have access to a variety of interoperable equipment. The standard is updated every two years with the latest version being IRIG-106-17. The release of IRIG-106-17 means flight test engineers now have a new list of transmitter performance features to understand and to track during the daily operations. This paper provides an overview of these new features as well as the associated command structure as published in the standard.

2:40 p.m. **"Why We Hatin' on ARTM CPM?" 554**
19-13-03 Kip Temple, Edwards AFB

Why hasn't the Aeronautical Mobile Telemetry community adopted IRIG 106 compliant ARTM CPM as their preferred waveform for the transmission of telemetry data? Telemetry receivers in the marketplace today exhibit gains in detection efficiency and resynchronization speed that far exceed products of just a few years ago. Past papers have shown the link performance comparison between the SOQPSK-TG, the new waveform standard, and ARTM CPM has narrowed since ARTM CPM was first standardized. This paper will present the latest performance comparison between these two waveforms during a controlled test throughout various flight conditions. A comparison of the one true measure of

overall link performance, Link Availability for each waveform is presented, comparisons are made, and results are discussed.

3:00 p.m. **"Channel Estimation Using Gaussian Process Regression" 564**
19-13-04 Richard Simeon, Erik Perrins & Taejoon Kim, University of Kansas

Gaussian process (GP) regression can be used in the interpolation of observed periodic channel estimates in OFDM transmission systems over both time and frequency in small-scale fading environments. Previous GP regression studies used the popular radial basis function as the GP kernel. In this study, we examine the performance of GP regression using a Bessel kernel with a semi-static hyperparameter vector. Results show that GP regression using the Bessel kernel outperforms the radial basis kernel, as well as traditional interpolation methods such as cubic spline and FIR interpolation, especially when training symbols are spaced far apart in time with respect to the channel coherence time.

Thursday, October 24, 2019, 9:00 – 10:40 a.m. Bronze 2

Session 14 Range System & Mobile Ground Systems

Chair Tab Wilcox, Yuma Proving Ground, Instrumentation Data Programmer TRAX International

9:00 a.m. **"Analysis of Inertial Measurement Data from a Model Rocket Payload" 573**
19-14-01 Benjamin M. Francis, Paul Blackhurst & David Long, Brigham Young University

This paper is on data analysis from small model rocket payloads called femtosats. A femtosat is a small-scale telemetry device used to measure the inertial motions of a model rocket. This student-designed circuit board includes a simple inertial measurement sensor that collects acceleration data in the form of x,y,z vectors which are then transmitted to a radio ground station. The focus of this paper is on the analysis of the data collected from the inertial measurement sensor and how it can be interpreted. A comparison is made with other methods of data interpretation to verify the same outcome as an experimental control.

9:20 a.m. **"Control Failures in an Unmanned Aerial System and the Potential for**
19-14-02 **Stateless Control" 578**
Kyle Norland & Michael Marcellin, The University of Arizona

To participate in the 2019 SUAS competition, an Unmanned Aerial System (UAS), was built. Unfortunately, several critical failures occurred, including an unwanted circling behavior, and an unnecessary self-crash. The analysis of both behaviors revealed surface level errors in the scripts and devices that were used, but also a deeper flaw in the architecture of state based behaviors and conditional state

transitions. To address these failures, an alternative architecture based around stateless controls was designed and tested. It successfully resolved the issues and seems to hold promise as an alternative control system architecture, especially in non-linear environments.

9:40 a.m. 19-14-03 **"LTE-Based Aeronautical Mobile Telemetry - Lab and Field Test Experiments" 588**

Kiran M. Rege, Erick Beck, Shobha Erramilli, Sarry Habiby, William Johnson, Achilles Kogiantis, Nan Maung, Zulfiquar Sayeed, Anthony Triolo & Jeffrey Young, Perspecta Labs

Aeronautical mobile telemetry based on 3GPP's LTE standard is implemented in a proof-of-concept system. The solution tackles the large Doppler shifts in flight tests using an appliqué that is placed between transmit/receive ports of the Test Article (TA) and the antennas. This appliqué estimates the Doppler shift and proactively compensates for it on the uplink signals transmitted by the TA. The overall system has been tested under different operational conditions in a lab setup and in the field. In the lab setup, the desired conditions are created with software-defined-radio-based channel emulators. In order to carry out field tests, an operational LTE network has been created at Edwards Air Force Base with two base stations, backhaul links and a core network. In this paper, we provide descriptions of the lab and field test setups, and the results of several tests that have been carried out to date. The results of the tests lend strong support to the viability of this AMT solution.

10:00 a.m. 19-14-04 **"Design and Research of Real-time Monitoring Program Development System for Civil Aircraft Flight Test Data Based on WPF" 598**

Wei Mao, Liu Tao, Can Feng, Feng Wang & Jiayi Liang, Flight Test Center of the COMAC

The real-time monitoring program of flight test data is an indispensable support tool for the large-scale civil aircraft flight test. With the continuous deepening of the networked test system, a large number of complex flight test parameters pose a huge challenge for the development of monitoring programs. Based on the WPF platform, this paper uses XAML files, reflection, and Data Binding to design a system for developing real-time monitoring programs for flight test data. On the design side, the system realizes the rapid integration and management of the monitoring program by dragging and dropping the display control, shortening the preparation cycle in the past few weeks to several hours; on the running end, the system can drive hundreds of monitoring terminals in real time by using the three-layer architecture. The system provides technical support for the first flight of the large passenger aircraft C919.

10:20 a.m. 19-14-05 **"Design of Airborne Real-time Monitoring System for Vibration Signal of Large Civil Aircraft" 608**

Liang Jiayi, COMAC Flight Test Center

The high frequency vibration signal can effectively reflect the structural strength of aircraft during flight test. In order to meet the need of real-time monitoring of vibration parameters of a large civil airliner, an airborne real-time monitoring system for vibration signals is designed and developed. Development of airborne real-time monitoring software for high-frequency signals based on C#. The software is received and analyzed the network data of the airborne acquisition system, processed the time domain signals by FFT and power spectrum transformation, and realized the graphical display. The software can provide a strong guarantee for the monitoring personnel to know the status of the aircraft in time. This System has been used in flight tests and received positive reviews.

Thursday, October 24, 2019, 9:00 – 11:00 a.m. Bronze 3

Session 15 Software Systems & Tools 2

Chair **Mike Gaines, Engineering Representative**
Elotek Systems, Inc.

9:00 a.m. **"A Systems Engineering Approach to Master Measurand Lists and Their**
19-15-01 **Metadata" 613**
Billy Wells, Northrop Grumman

A system engineering approach to master measurand lists allows database designers to leverage metadata to improve data organization and management. As data acquisition systems become more complex, the management of sensors and their measurands must also advance. Traditional tabulated measurand lists of several hundred measurands are typically generated from email or verbal requests. Modern data acquisition systems with thousands of measurands are more complex than ever, causing these tabulated spreadsheets to become unwieldy and unmanageable. Modern database structures can easily handle these lists by organizing measurands by their metadata. This also provides an archival process to track the maturity of the instrumentation system design. By aligning the requirements of the measurand database with data acquisition system requirements, designers can ensure their data acquisition system is within constraints such as bandwidth, storage capacity, power consumption, size, and weight.

9:20 a.m. **"Data Collection and Analysis Techniques for Solar Car Telemetry Data" 622**
19-15-02 Michael Rouse, Miranda Sauer & Kurt Kosbar, Missouri S&T

Data collected from a solar car is monitored in real-time, which allows for intelligent decision making, efficient debugging, and high-quality testing for solar car teams. This paper compares three databases (MySQL, PostgreSQL, and MongoDB) to determine the optimal database system that should be used at solar car competitions. Each database system was tested using simulated solar car data to measure read and write speeds, and quality of performance on a low-power computer. Data were analyzed and displayed with custom interfaces to improve the user experience at solar car competitions.

9:40 a.m. **"Applications of Autonomous Navigation in Next-Generation Mars Rovers" 631**
19-15-03 Sarah Dlouhy, Ethan Arneson & Kurt Kosbar, Missouri S&T

This paper describes a module used to provide autonomous navigation and obstacle avoidance to a teleoperated prototype Mars rover designed to compete in the 2019 University Rover Challenge. For the competition's Autonomous Traversal task, the rover must be capable of traversing difficult desert terrain in search of visual waypoints. Our design uses a custom Navigation Board (NavBoard), a mobile robotics computer, and a sensor capable of producing a dense point cloud. NavBoard provides quaternion-based orientation data, distance measurements from a 1D LiDAR system, and GPS data over ethernet to a mobile robotics computer. This computer derives a 3D point cloud from a three-headed collinear stereoscopic camera then processes that data along with the data from NavBoard to determine the correct action to navigate through sparsely mapped terrain.

10:00 a.m. **"Latest Development Status on the Commercial Derivative Aircraft Based**
19-15-04 **Instrumentation Telemetry System (CBITS) Program" 639**
Scott Kujiraoka, GBL Systems

The CBITS project will provide an advanced airborne telemetry (TM) system and capability to support the test and evaluation (T&E) of current and future military weapons and defensive systems. In conjunction with the Range Support Aircraft (RSA) contracts, CBITS will provide an autonomous airborne T&E asset capable of supporting Major Range and Test Facility Base (MRTFB) government ranges. CBITS will develop an improved S-Band airborne TM capability and a new L- and C-Band TM capability as a result of frequency spectrum selloff issues. These improved TM capabilities, along with the existing airborne Flight Termination System/Command Destruct (FTS/CD) capability, existing radar for Range Surveillance (RS) and Range Clearance (RC), and communication systems will be integrated into a Gulfstream G550 Airborne Early Warning (AEW) RSA which will be replacing the current NP-3D Remote Area Safety Aircraft (RASA). This paper will discuss the latest developmental status of the CBITS project.

10:20 a.m. **"Validation Protocol - The Missing Puzzle Piece" 643**

19-15-05 Jakub Moskal & Mieczyslaw Kokar, VIStology, Inc.; Austin Whittington & Ben Abbott, Southwest Research Institute; Jon Morgan, Edwards

In multi-vendor T&E systems, a single hardware vendor cannot anticipate the dependencies on the settings from hardware manufactured by other vendors, or the systemic constraints that are specific to a particular customer. The T&E community has recognized the fact that MDL and TMATS XML are not sufficient to address this problem alone, and that there is a need for a separate, constraints language. Constraints written in such a language can be validated by a third party validation engine, without relying on any particular vendor's software. To this end, we developed the concept of TACL, a candidate for the standard constraint language, and demonstrated it with a reference implementation of a TACL engine integrated with the iNET System Manager. In this paper, we argue that this integration should be standardized in the form of a Validation Protocol in order to turn the existing system into a loosely-coupled, standards-based architecture.

10:40 a.m. **"Flight Test Real-time Monitoring System Based on Automatic Identification**
19-15-06 **of Test Points" 652**
Liu Shenghu, Yang Zhe & Ye Bing, Chinese Flight Test Establishment

In order to improve the flight test efficiency of the test plane, an intelligent real-time monitoring system based on automatically identifying test points was designed. The system decomposes the entire flight process into multiple test points, each with clear tasks and requirements. Through the prior knowledge of the field experts to manually identify the test points, and the test plane's parameters change at different test points are analyzed in depth, the key parameters affecting the test point identification and their variation rules are extracted, and the test point identification knowledge base is constructed. The automatic detection algorithm of test points is designed. Combined with the real-time task evaluation technology of flight test, a real-time monitoring system for flight test based on automatic identification and intelligent evaluation of test points is developed. The use shows that the system effectively improves the flight test efficiency of the test plane.

Thursday, October 24, 2019, 9:00 – 10:40 a.m. Bronze 4

Session 16 Antenna & RF System 3

Chair Tasmeer Alam, PREP Researcher
National Institute of Science and Technology

9:00 a.m. **"JFLUTTER. Real Time Flutter Analysis in Flight Test" 658**
19-16-01 Pedro Rubio & Francisca Coll, Airbus Defence & Space

During the development of an aircraft it is mandatory to demonstrate that the aircraft is free from flutter within its operational flight envelope. This piece showcases JFlutter, a flutter analysis tool developed within Airbus Defence & Space Flight Test Analysis Tools. JFlutter allows the analysis of this phenomenon

in real time monitoring, using telemetry data and post flight mode. Using the FxS dataserver as data provider, a reliable data gathering mechanism has been used for this critical tool. As flutter means aeroelastic instability, potentially dangerous, flight safety becomes a main requirement. For safety reasons and in order to reduce overall test program duration it is necessary to check predicted frequencies and damping in real time / monitoring.

9:20 a.m. **"High-Performance Extensible SOQPSK (E-SOQPSK) Modulation**
19-16-02 **Waveforms for Aeronautical Mobile Telemetry Communications" 668**
Paul Cook, Cheng Lu, Rajeev Argula & Gyorgy Sasvari, Curtiss-Wright Defense Solutions

To utilize the resilience to multipath and rapidly varying Doppler shifts offered by a multicarrier (MC) Orthogonal Frequency Division Multiplexed (OFDM) modulation waveform, and the high transmitter power efficiency offered by a single carrier (SC) Shaped Offset Quadrature Phase Shift Keying (SOQPSK) modulation waveform, we propose a novel Extensible Shaped Offset Quadrature Phase Shift Keying (E-SOQPSK) modulation waveform. E-SOQPSK is an OFDM structured single carrier modulation waveform, configurable to include OQPSK, SOQPSK, or m-QAM. Preliminary laboratory results confirmed its low Peak-to-Average Power ratio (PAPR) and high spectrum efficiency. Preliminary simulations demonstrated multipath resilience of E-SOQPSK waveform by utilizing OFDM structure-based Frequency-Domain equalization at receiver.

9:40 a.m. **"APSK Symbol Timing and Carrier Phase Synchronization on an FPGA in a**
19-16-03 **C-Band Telemetry Receiver" 678**
Jason Baxter & Erik Perrins, University of Kansas

This paper presents the implementation of a standard PLL-based timing and phase synchronization system on hardware using an FPGA. The synchronization system is shown to successfully recover a 16-APSK signal despite offsets in phase and frequency between the transmitter and receiver local oscillators. Furthermore, it is shown that system performance, in terms of symbol times required to achieve lock, is comparable to double-precision floating point simulations despite using fixed point numbers with as few as 5 fractional bits for most computations.

10:00 a.m. **"Doppler Power Spectra from Vehicle-to-Everything Propagation**
19-16-04 **Experiments" 688**
Kalin Norman, Benjamin Jensen, Michael Rice & Willie K. Harrison, Brigham Young University

This paper presents the results of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) propagation experiments. The experimental results are summarized by Doppler power spectra. Our measurements indicate the need for a dynamic system that can handle the variable channels experienced in vehicle-to-everything communications.

10:20 a.m. **"The Good, The Bad, and The Non-Circular Signals" 695**

19-16-05 Stephanie Tsang & Tamal Bose, University of Arizona; Al Samuel

Second-order (SO) non-circularity is a statistical property that is used to classify signals. Signals with SO non-circularity are extensively used in communication and radar systems. The SO non-circularity property is generally useful in the application of array processing techniques for extending antenna apertures. Exploiting this non-circularity property for a multi-faceted set of communication-type and radar-type signals is the objective of this study. For a given type of signal, the circularity quotient and its properties are tested and evaluated in terms of parameters such as the modulus of its phase, complex covariance, pseudo-variance, the angle orientation of the ellipse, its eccentricity, and other relevant properties are calculated. A MATLAB simulation was developed to expeditiously and efficiently identify circular versus non-circular signals and for computing several statistical measures of a SO, non-circular signal.