I&T Systems

Standard In-Orbit Test System Description

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IOT Systems

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Introduction

1.1 Summary

- IOT Systems would be pleased to demonstrate our system and existing software capabilities. For a partial demo of some of the features of the *Standard IOT System* please see our [demo page](#).

- Our *Standard IOT System* offers high-quality, field-tested in-orbit test (IOT) measurements, processing and control software, and proven hardware design.

- We can assemble, install, test, and deliver the *Standard IOT System* that generally exceeds specifications within tight schedules.

- Because we have developed and tested most an extensive set of measurements, the amount of customization we must perform to meet specific requirements is generally minimal.

- Therefore, technical, schedule, and cost risks are minimized compared to custom-built but untested software.

- We will provide i.p.f.d/e.i.r.p. stability; beacon e.i.r.p., frequency, and cross-polarization; and spectrum analyzer monitoring with screen capture; and other measurements that add value.

- With LAN connections and a workstation, measurements can be run from any location in the world i.e. an engineer can run measurements from his or her office.

- Via VPN, IOT Systems can provide cost-effective, real-time support to our Customer with communications between IOT Systems and the host facility.

- Additional workstations can be added to the network at the Customer's discretion for greater operational flexibility.

When COMSAT was the U.S. Signatory to both INTELSAT and Inmarsat, COMSAT became well-versed in all aspects of communications satellite technologies and applications. IOT Systems was spun off of COMSAT Laboratories after the Lockheed Martin merger.

Our approach is based on over 4 decades of experience with automated in-orbit test (IOT) and communications systems monitoring (CSM) systems. For example, we designed, fabricated, and installed IOTs and CSMs for EUTELSAT, INTELSAT, GTE, LORAL Skynet, Orion, as well as ground station status and control for NASA's *Advanced Communications Satellite Technology* (ACTS) Ka-Band program.

For EUTELSAT we built and installed their IOT facility in Rambouillet (France) which has been used to test the EUTELSAT II satellites F1, F2, F3 and F4. We also worked with EUTELSAT to upgrade their IOT facility to support an automated dual-station capability. One station transmits and measures an uplink test carrier while a second station hosting the primary IOT facility performs measurements on the downlink. IOT equipment in the uplink station is remotely controlled by the primary IOT facility located in the second station. We since have performed two station testing for several customers with the existing software base.

During 1993, we built and installed a highly automated IOT facility for Hughes' testing of their DirecTv™ direct-broadcast satellites (DBS), and supported several of their IOT of the first DirecTv™ satellites launched starting in December 1993. In addition, we are upgrading an older Hughes IOT system(now Intelsat), which we had built, for testing SBS satellites and is now part of the current Intelsat system of test facilities all implemented with The *Standard IOT System*. When DirecTV was leaving the factory acceptance test (FAT) they mentioned that there is a lot more power and tools than what we had previously mentioned. It is HARD to fully describe all of the tools that are in the system, and in the 30 years since that meeting, many more tools have been added, we continually strive to improve the capability of the system. Since 1997, we have supported nearly 100% of Intelsat's In-Orbit Test campaigns.

In 1998, we delivered 3 portable *Standard IOT System*s which enabled Space Systems/LORAL to provide Delivery-In-Orbit (DIO) for the first time and as a result, their business exploded.

In the 1980's we started our UNIX based IOT development and in the early 1990's, we developed a system which we call our *Standard IOT System*. The *Standard IOT System* incorporates a very large set of standard software and hardware components required to build a state-of-the-art IOT facility. We have found that most IOT systems share a core set of capabilities that, once implemented and standardized, can be re-used from one IOT system to another, resulting in substantial savings of cost and development time. Our *Standard IOT System* includes numerous IOT measurements, such as i.p.f.d. and e.i.r.p., gain transfer, G/T, In-Band and Out-of-Band frequency response, and translation frequency offset, as well as additional stability measurements for i.p.f.d., e.i.r.p., G/T, and beacon e.i.r.p and frequency. In addition, we have developed and tested many other measurements including a *Fastsweep* frequency response and a QPSK-modulated-carrier e.i.r.p. measurement. We use a fast transfer method for finding saturation and we also have FastTransfer as a stand-alone measurement. Since the system is modular and extensible other measurements can be easily added to increase the flexibility and capability of an IOT system.

The original COMSAT Laboratories' accomplishments in IOT systems development was led by Dr. Christoph Mahle and Dr. Vasilis Riginos. These two recognized experts were at the helm of all of the original COMSAT IOT work, providing direct project and line management responsibility and technical expertise. As Dr. Mahle reported directly to Dr. John Evans, President of COMSAT Laboratories. In 1995, they all retired and Steve Teller, the father of *Standard IOT System,* assumed management responsibility for all further development of Measurement System development for COMSAT Laboratories. In 2002, the business unit was spun off as IOT Systems.

Since IOT Systems already has 100% of the necessary software:

- The amount of custom-build software – and its associated cost – necessary to fulfill Customer-specific requirements is minimized or entirely eliminated.

- This software has already withstood field-testing in operational IOT systems and, therefore, offers a high degree of **reliability**, **robustness**, and **low risk**.

- Because customization is required for only those portions unique to a particular Customer's application, we can assemble, deliver, install and test a fully operational system to tight delivery schedules.

We offer our *Standard IOT System* customized as necessary, not building a system from the ground up.

An alternative to this pre-tested, highly reliable customized system is a situation in which a supplier proposes to build a system from the ground up. Although this approach appears to provide what is specified, it never really does because there are hidden drawbacks. These include:

- As a first-of-its-kind product, the hardware design and software are unproven and generally requires extensive debugging and fine-tuning before becoming fully operational.

- The cost and time needed for labor-intensive custom software development are difficult to estimate and control. Once committed, the Customer has little choice but to work with the supplier to obtain a satisfactory system, which generally costs more and takes longer than was originally bargained for.

- Because suppliers often underestimate the time and cost involved in building such a complex system from the ground up, mounting budgetary and schedule pressure may force corner-cutting to meet approaching delivery deadlines. Quality control is often severely compromised in the rush to deliver.

- A system built from scratch does not provide long-term flexibility, nor an evolutionary growth path, to accommodate changed or expanded mission requirements that an IOT system inevitably experiences during its operational lifetime.

Our *Standard IOT System* software undergoes ongoing maintenance to improve its reliability, functionality, flexibility, and adaptability, providing a built-in evolutionary path to a more robust system. The systems has been field tested through the testing of over 100 communications satellites.

1.2   What Our *Standard IOT System* Offers

We offer our *Standard IOT System* and a small amount of customization work for accommodating Customer-specific requirements not already provided by our *Standard IOT System* . Our *Standard IOT System* offers a rich set of features and functionality at an attractive price. Some of the features are described below:

- Local and wide area networking support allows remote measurement control.

- Our *Standard IOT System* supports networking, including remote access and control of the IOT measurement equipment. Figure 1-1 illustrates the networked system architecture for IOT Systems' In-Orbit Test systems.

- Our software is of such modularity that it allows the software system to execute in a distributed processing system architecture spanning a number of dissimilar workstations. Several programs can be running on several different machines, which provides a more robust and flexible system.

   For instance, separation of the user interface from the measurement allows for a distributed execution environment and measurement scheduling. Because the measurement user interfaces (MUI) are logically and physically separate programs from the measurement program, they can execute in different computers connected to the local area network at different times. Communication between them is via an inter-process mail subsystem that we developed for this purpose that operates across machine boundaries. i.e., our mail subsystem supports **intermachine** inter-process communications. The narrative in the next section shows MUIs in action, as would be experienced by an operator or engineer conducting IOT measurements.

   Figure 1-2 illustrates the idea of a distributed execution environment that allows multiple workstations and users, adding richness and flexibility to our *Standard IOT System* design.
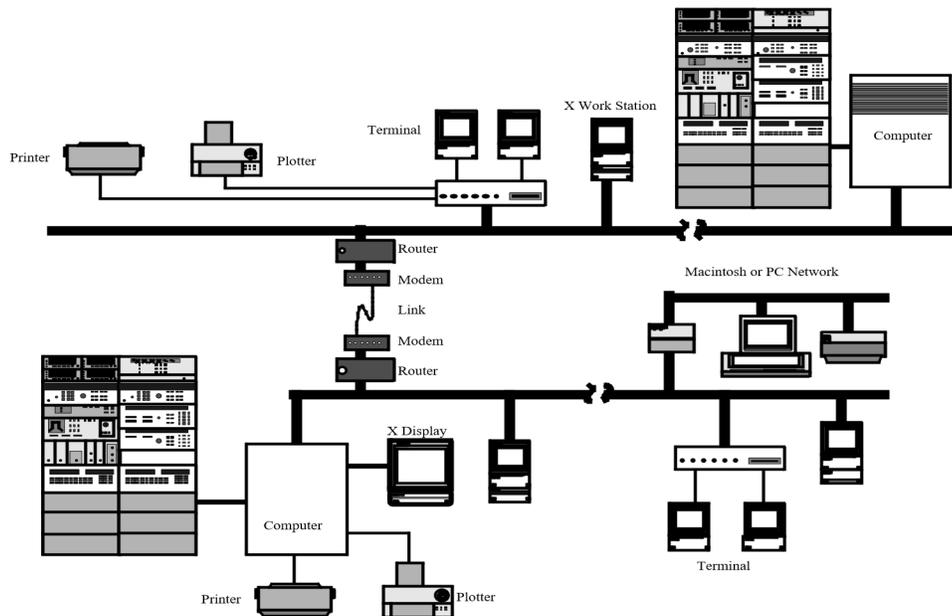
Figure 1-1 *Networked System Architecture*

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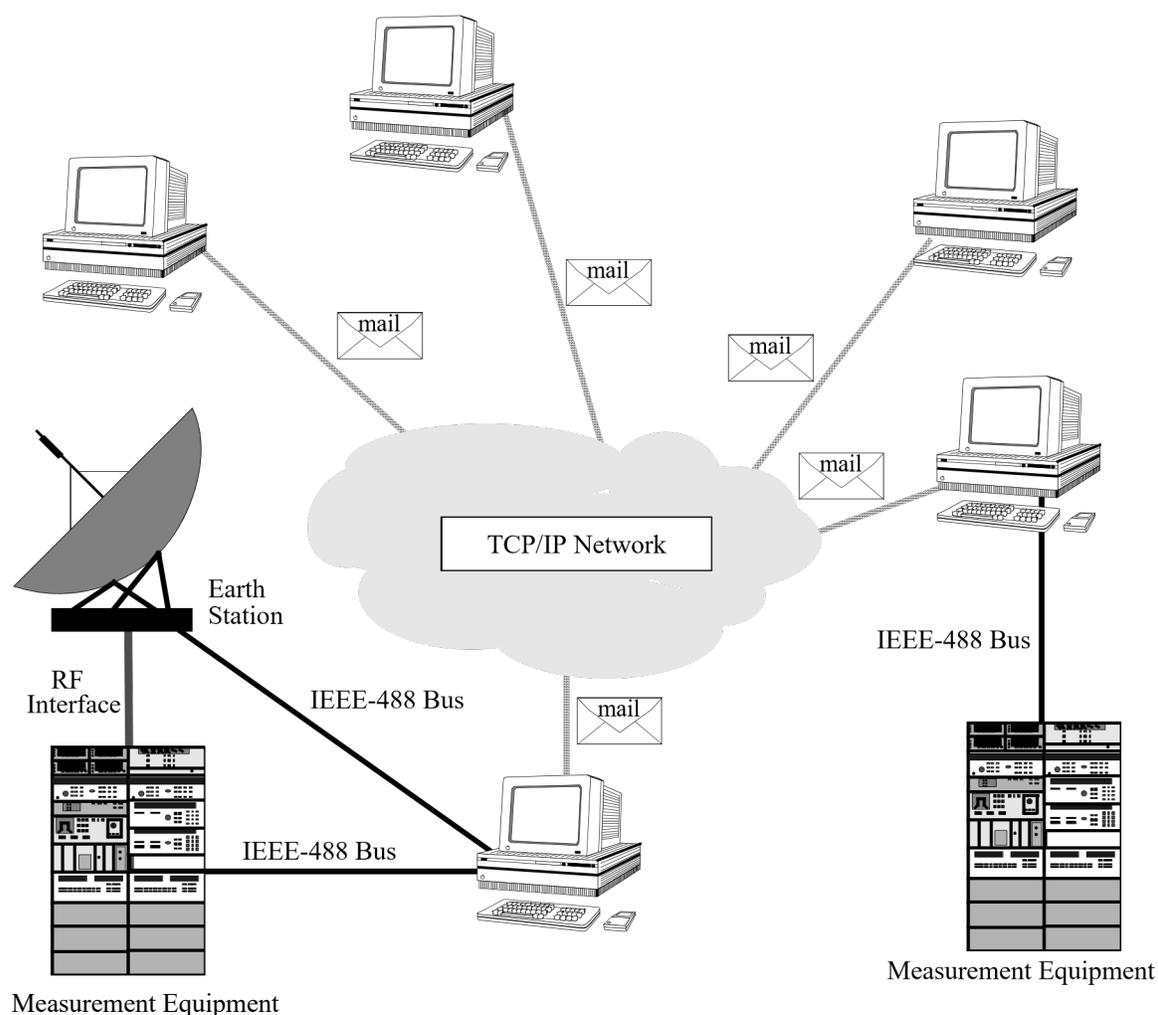
Figure 1-2 *Distributed Processing Execution Environment*

- The user interfaces are implemented as OSF/Motif windows that permit easy to use point-and-click mouse input. Input errors (e.g. input out of range or wrong type) are detected and the user notified, so that bad input is caught before measurements are scheduled and executed.

- The Graphic Mimic Panel, described in Section 4, displays status and configuration in real time and enables the user to control hardware switches.

- Data-driven measurements provides low-cost easy customization of the system's behavior.

  Our microwave measurements and supporting software are data-driven to the maximum extent possible so that customization is accomplished by editing static ASCII encoded data files rather than modifying code. Code modification is a much more costly and time-consuming process. Customization of the system is readily accommodated in our data-driven design.

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- With our scheduler, measurements can be scheduled by the user at the user interface window to run at any time, day or night, and to be repeated at a specified frequency over a specified duration.

  Non-interactive measurements (those that do not require an operator to be in attendance when the measurement is running) can be scheduled to run at any user-specified time and the measurement can be repeated at user-specified intervals.

- Our *Standard IOT System* supports multi-user operation when additional workstations are added.

- We provide capability for measurement database search and retrieval for printing and plotting.

- Print and plot style is controlled by style files which are easily customized as they are ASCII files and can be easily edited.

1.3 Why We Chose A *Standard IOT System*

Our *Standard IOT System* was developed to achieve tested, high-reliability IOT measurements and processing and control software. Because it is reusable, we offer high-quality, robust, tested software and system functionality at modest cost compared to custom-built software. This subsection discusses some of the rationale underlying the *Standard IOT System* Commercial-Off-The-Shelf (COTS) product.

Although cost, schedule, and approach for the hardware aspect of IOT and similar measurement systems are generally well-understood and well-controlled, it is increasingly the volume, sophistication, and complexity of the software, often real time in nature and involving human interaction, that has come to dominate IOT systems' cost and schedule.

A principal method for reducing the cost of new systems is to reuse previously tested high-quality software, thus significantly lowering both schedule and performance risks associated with new software development. *Standard IOT System* COTS product has tested over 100 satellites for most major satellite operators and manufacturers.

To facilitate the efficient development of measurements and complete systems, COMSAT Laboratories developed over twenty years and IOT Systems has further developed the system over another twenty years a generic microwave measurement software system built upon an engineered "platform" of reusable software services and facilities that are common to IOT measurements and systems. The *Measurement Processing and Control Platform (MPCP)* provides modular, tested software components for inter-process/intermachine mail communications; scheduling of IOT measurements at any time of day and resource management; a system-wide shared information depository; object-code libraries of functions for user interface support, measurement support, instrument control, IEEE-488 bus management, error handling, mathematical functions, and utility functions (e.g., string and time processing) that can be linked into applications programs; and supporting subsystems for database management, report generation (prints and plots), and interactive editing of plot files.

The approach of developing a robust software-engineered platform architecture and implementation is applicable to new IOT systems faced with escalating software demands which must be cost-, schedule-, and quality-controlled. The engineered platform methodology and implementation results in desirable software characteristics in terms of

design and development effort, life cycle characteristics (reusability, maintainability, expandability, portability, evolution), quality (methodology, robustness, consistency, flexibility) and capability (remote control, networking, concurrent measurements, distributed systems, user-driven changes) when compared to an ad hoc software development methodology. Appendix A, a reprint of a conference paper presented in 1992 at "The 14th International Communication Satellite Systems Conference and Exhibit" sponsored by the American Institute of Aeronautics and Astronautics (Washington, D.C., March 22-24, 1992), provides additional discussion of our choice of developing our *Standard IOT System*.

The initial IOT system development at COMSAT Laboratories was been led by Drs. Mahle and Riginos. During their 30-year tenure at COMSAT Laboratories, they pioneered techniques for testing satellites in orbit. As they wrestled with the challenges of testing, monitoring, and investigating in-orbit satellites, they and their colleagues formulated a general solution to the IOT problem of the best strategy for building high-reliability IOT systems in a manner that could be easily reproduced from one system to the next without requiring extensive and costly customization each time. Hardware and software were developed by the same people, ensuring close coordination and integration of the two domains. The solution – a distillation of this cumulative experience – resulted in hardware, measurements, and processing and control software for a universal IOT system, but which is directly applicable to Customer-specific systems.

During over forty years of experience in designing, building, and installing IOT systems, we have observed that IOT systems are quite similar in their functionality and operational requirements. This insight led to the development of COMSAT Laboratories' *Standard IOT System* in which most of the commonality across IOT system was developed in as general a manner as possible. Thus, for any particular IOT system requirement 100% of the requirements are accommodated in the *Standard IOT System* and selected options. The particular and unique requirements then require a relatively small amount of customization work. We can deliver a complete, easily customized, full function In-Orbit Test (IOT) System without writing ANY code. The *Standard IOT System* COTS product is designed to test any communications satellite and be integrated into any earth station and connected to ANY number of antennas in any satellite band. The *Standard IOT System* COTS product was designed to fully automate measurements, allow for interactive manual control of instruments remotely, we initially built the systems for us, to be able to provide high level tools for anomaly investigation, and help decern between space and ground problems.

Although a new IOT system has some unique features and requirements, our task in building a reliable, robust IOT system is principally one of modifying our *Standard IOT System* physical design somewhat and assembling a system rather than developing a fully custom system from the ground up.

However, because our *Standard IOT System* embodies a pre-existing solution, cost effectiveness to our potential customers is preserved when customization effort is minimized. As customization effort increases, cost and schedule are impacted and quality approaches that of any custom system.

Therefore, although our system is deliberately implemented with respect to maximizing generality, expandability, and flexibility in terms of ongoing software development, maintenance, and improvement, it can accommodate a reasonable amount of requested customization and we can perform this customization.

It is more appropriate to consider our *Standard IOT System* as **assembled to order, not made to order**. We are **NOT** offering a custom-built system from the ground up. Rather, starting from the requirements, we modify somewhat our existing off-the-shelf *Standard IOT System* with a selection of options chosen to fulfill Customer-specific requirements to provide the most cost-effective solution.

To maintain an overall modest cost (given the functionality of our *Standard IOT System* and substantial value-added features such as networking and additional, non-required IOT measurements), wherever possible, we favor the most-effective approach to provide a functional, compliant system at the least cost.

The typical customization to the Standard IOT System is limited to user configurable data description files that indicate how the system is connected to the earth station and other site-specific information. The number of antennas, number of complete systems at the site, the mimic panel layout, number of panels, plotting, everything is very customizable without ANY software modification. As mentioned elsewhere, we use our extensive libraries and object-oriented methods which allows for dramatic code reuse, but we go beyond that, we use description files that really handle all of the installation-to-installation differences which what allows us to deliver a system with ZERO software development. These description files can be modified to expand the capability of your system in the future, without any new software.

1.4   The Build-From-Scratch Alternative

The principal alternative to our *Standard IOT System* solution is a build-to-order procurement in which the supplier bids to build a custom system. The custom-build system apparently offers the Customer what he wants: a custom-built system that ultimately works. However, the disadvantages of the custom-built system must be carefully considered and weighed. The custom-built system, by definition, is a one-of-a-kind, first-of-its-kind product. Custom built systems are usually very difficult to implement against tight required delivery schedules. Typically, custom-built software takes longer, and costs more than originally planned or budgeted. A supplier of a custom-built system typically underestimates the schedule and cost and, because of mounting budget and schedule pressures, cutting corners to meet the delivery deadlines may result, with additional work usually required to bring the system into specifications, added costs, and delays. As a result, quality may be compromised. Because the software (and hardware configuration and system design) are custom, overall system quality and reliability are suspect.
An analogy illustrates the pitfalls of custom-built systems. When an engineer requires a spectrum analyzer, he (or she) goes to Hewlett-Packard, Tektronix, Anritsu, or another supplier and purchases an off-the-shelf instrument. One then "customizes" it by selecting from among a set of options offered by the manufacturer. The manufacturer may sell the basic spectrum analyzer for tens of thousands of dollars and options are extra. Delivery is typically a few weeks to a few months. The engineer can trust the underlying quality of the instrument because the manufacturer has spent a great deal of effort, time, and money to produce the highest quality, highest performance instrument for a specified price.

Now consider a second engineer who also desires a spectrum analyzer. Rather than buying a "standard", commercial off-the-shelf instrument, he seeks a custom system because of special requirements. If the "customization" is relatively cosmetic and not basic, a manufacturer may be willing to customize his standard unit to the particular requirements. But, as the "specials" move from cosmetic to the basic "guts" of the instrument, the cost and time increase rapidly, while quality, because of the one-of-a-kind nature of the special, suffers. After all, if the

manufacturer hopes to sell many of his standard spectrum analyzers, he will invest resources to ensure high quality, but if he hopes to sell only one "custom" instrument, then his motivation to ensure quality is not the same, nor will the customer be able to pay for the same. Whereas a standard, commercial spectrum analyzer is obtainable for tens of thousands of dollars in a few weeks or months, a truly custom instrument may cost hundreds of thousands of dollars and may require well over a year.

The *Standard IOT System* purchase can be initiated by contacting Steve Teller, President of IOT Systems via email at teller@iotsystems.com and follow up with a call at +1 301-892-6256 and please leave a message, we get a lot of spam calls.

For additional information concerning our *Standard IOT System*, contact:
Steve Teller, President of IOT Systems, Hagerstown Maryland 21742 (in U.S.A).
Telephone: (301) 892-6256 or by Fax: (651) 691-2940 (all in the U.S.A.), Email: teller@iotsystems.com

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Section 2

User Interface/Software

2.1 Management Summary

- IOT Systems offers a large suite of *available*, high-quality, field-tested software already developed.

- The *Standard IOT System* is multitasking, that is, it allows many operations to be done simultaneously (for example, a stability measurement is performed concurrently with plotting of previous measurements, while users are specifying new measurements).

- IOT software uses an easy to use and learn, industry standard (OSF/Motif), consistent, graphical user interface.

- IOT software has built-in networking capability which allows expansion to any number of workstations controlling the IOT instruments from remote locations. All workstations use the same user interface.

- The IOT uses sophisticated methods of instrument error detection and handling, ensuring reliable data.

- The IOT provides a large number of tabular and graphical reports, the style of which can be modified without any programming. These reports are formatted in industry standard (PostScript®) and are transportable across a large number of commercial applications such as word processors and spreadsheets.

2.2 Introduction

After developing specific IOT systems for over 15 years we articulated the main design requirements for a general IOT system[1] and we started developing such a system. The initial *Standard IOT System* software development was completed over 30 years[2] ago and has been continually refined and added to for the last 30 years. During this development the main principle was to provide high-powered IOT software which is as unobtrusive to the user as much as possible. To this end we made and followed several design choices:

1. We initially chose the UNIX operating system running on powerful relatively inexpensive and easily networked workstations and now employ Rad Hat Linux and use standard PC hardware.

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[1] Reference [5] on page B-1

[2] The software structure of this system is presented in references [3] and [4] on page B-1.

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2. We adopted X windows with OSF/Motif for the user interface, strictly adhering to the Motif interface standard[3] and the Apple Macintosh interface[4]. These standards and principles are the results of research work performed over the last 15 years[1] and are finally being used extensively in workstations and PCs.

3. We designed into the software distributed processing and instrument time-sharing principles[2] to allow both remote control and expandability.

4. We adopted object-oriented techniques (using the C++ language), thus modularizing and simplifying our code[3]. At the same time, we aimed at generalized code driven by tables and data so that it can be easily customized without lengthy programing. This not only minimizes programming error but empowers the user to further expand or modify the *Standard IOT System*.

5. We developed comprehensive object-oriented utility and instrument driver libraries. The instrument module handles all instrument access including initialization and exception handling. The use of these libraries coupled with a unified error reporting and logging scheme not only assures the user of data integrity but greatly simplifies measurement procedures. This simplification has two benefits: allows rapid development of new measurements and facilitates review of the code even by people not versed in the C or C++ languages.

To help explain the functionality and ease of use of the IOT, we will provide a narrative walk through, with many window displays, of a typical measurement session explaining relevant features as they occur.

The displays depicted in this session are dumps of real windows from the IOT Systems' *Standard IOT System*.

2.3 IOT User Interface Walk Through

When the IOT Computer is powered or re-booted, it sets the IOT system into a default initial condition. In this condition all sources, switches, attenuators, etc. are in a *safe* state. From this time on everything is under the control of the operator, via the Mimic Panel. When an automatic measurement is executed it sets all applicable instruments and switches to their desired state, performs the measurement, and then returns them to their default state. The actual default state is data driven and will be decided in cooperation with the customer prior to the IOT.

Figure 2-1 on page 2-3 depicts a typical IOT display in the middle of user session after several windows have been opened.

Several open windows are shown on the display: The IOT Control window, a Help window, a window with tabular measurement data, a terminal emulator window, and a window with graphical measurement data.

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[3]Reference [8] on page B-3

[4]Reference [16] on page B-3

[1]References [6], and [25] on page B-4

[2]These ideas are expanded on Reference [1].

[3]For details see Appendix E.
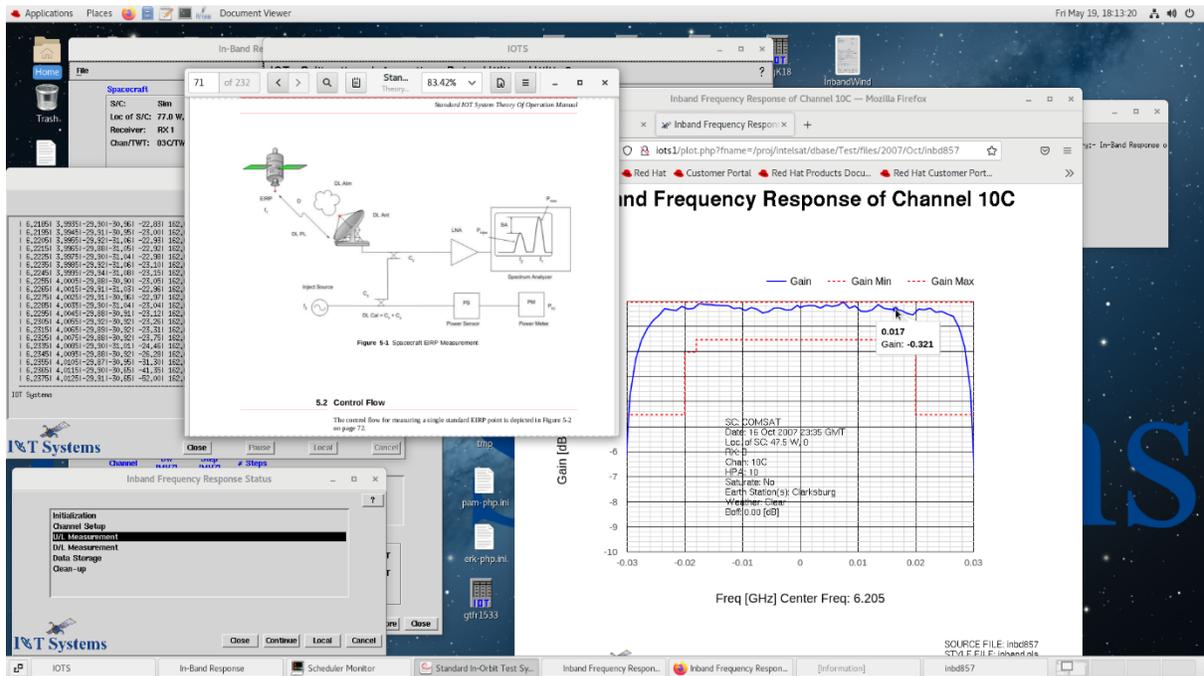
Figure 2-1 *A Typical IOT Display*

2.3.1   The IOT Control Window

The IOT Control window is the master control of the IOT and is shown in Figure 2-2. It provides menus for all of its functions, and for the most common functions, push buttons as well.
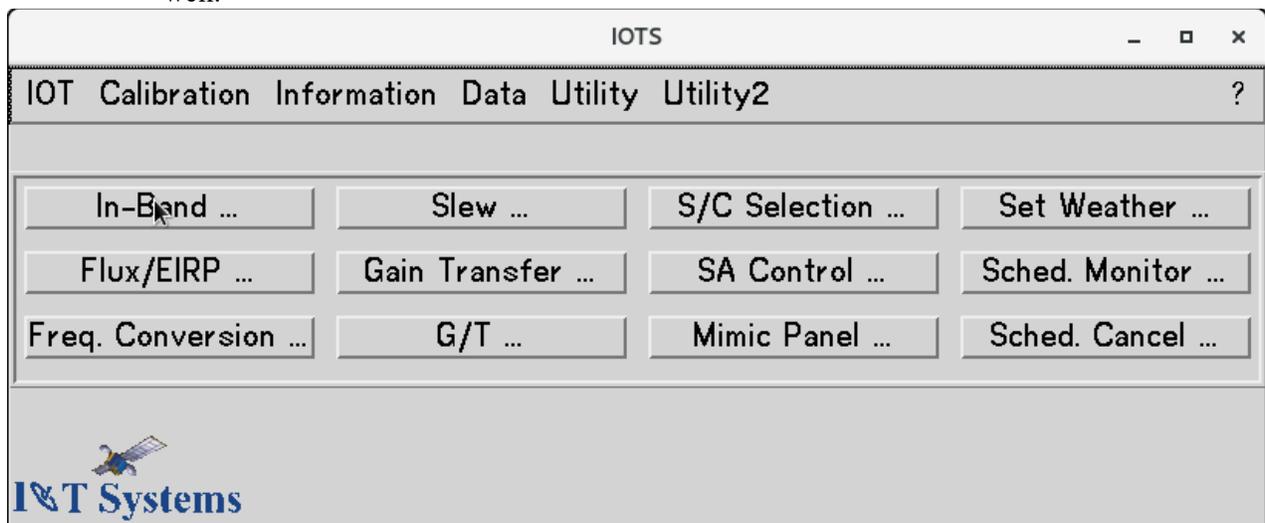
The symbol**"?"** in the upper right corner indicates the context sensitive help available to most IOT windows. In the case of the IOT several help choices are offered as shown in Figure 2-3.
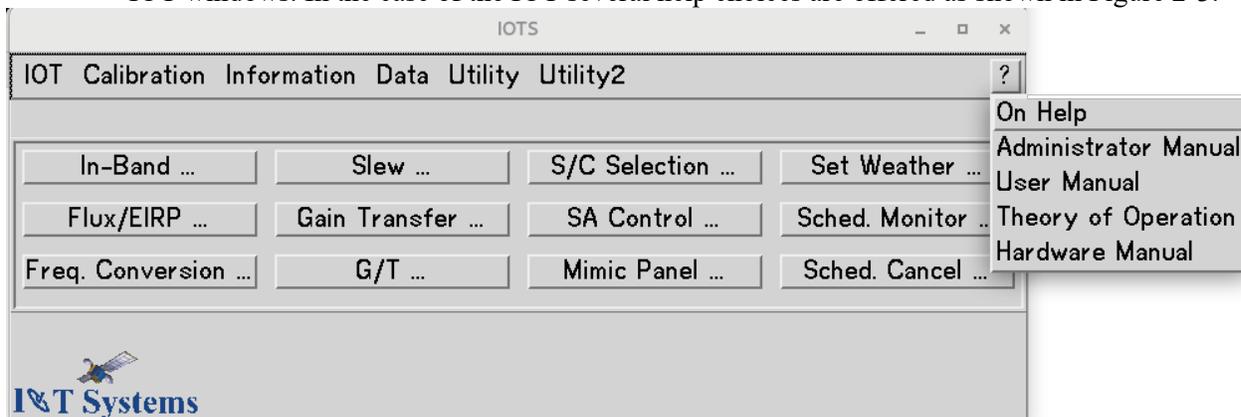
Figure 2-3 *Help Menu*

2.3.2   On-Line Help

Help is available on how to use the IOT help system, on controlling the IOT, the Administrator Manual, the User Manual, and the Theory of Operation Manual.

Let us click on the latter. We are presented with a new window (which we can move, iconify, or close) which shows the table of contents of the Theory of Operation Manual.

Figure 2-4 *Help - Topics*

The table of contents of the Theory of Operation Manual is shown in Figure 2-4. The Underlined Blue chapter headings are Hypertext buttons to the rest of the document, while the arrows at the bottom of the window are paging controls.

By clicking on the down arrow, we see the second page of the table of contents. If we click on "Chapter 5" the help window shows the first page of Chapter 5: EIRP. Again, we can browse through pages. Figure 2-5 shows the second page of the Chapter 5.

Returning now back to the IOT window, we click on the "IOT" on the menu bar near the top of the window. The window (Figure 2-6 on page 2-7) shows us the full range of IOT measurements available on the IOT.

We select from this menu the "Freq. Response" measurement.
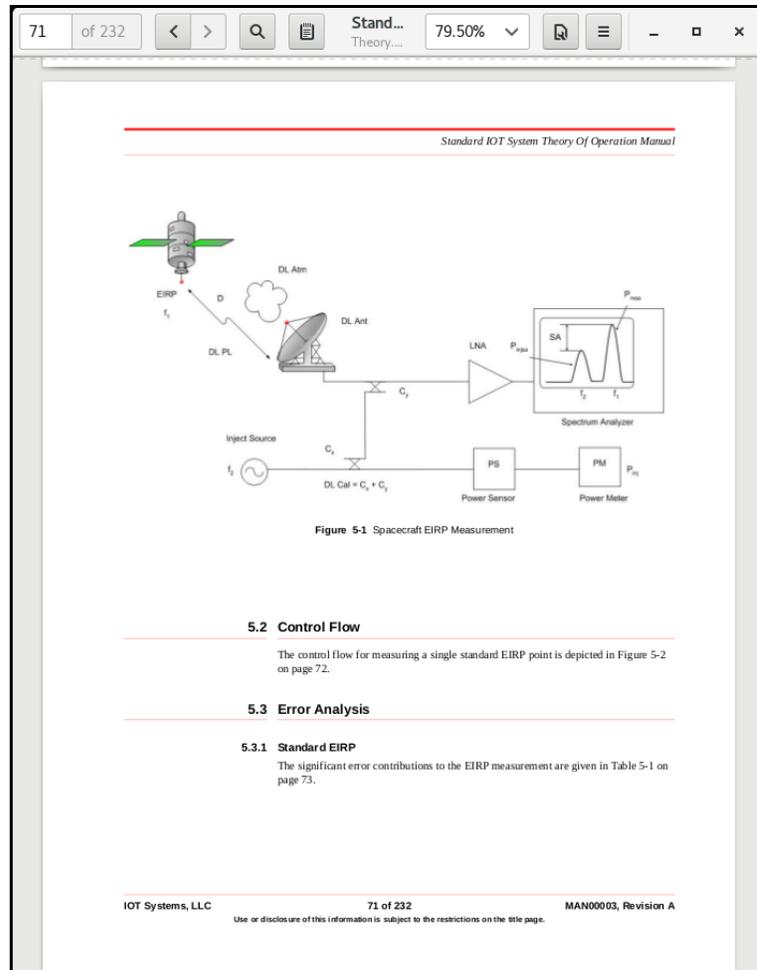
Figure 2-5 *Help- E.i.r.p.*

Again a new window appears. This window is the control window for the Frequency Response measurement.

2.3.3 Typical Measurement Control Window

The Frequency Response measurement window, shown in Figure 2-7 on page 2-8, like all measurement windows, consists of several panels:

the S/C panel - with spacecraft related information the Weather panel - with weather information selected by the user via radio buttons the Comment panel - where the user can enter comments to appear on the measurement data reports

the Control panel - with measurement specific controls and

parameters the Channel panel - with channel specific controls and

parameters the Schedule panel - which control the scheduling of the

measurement
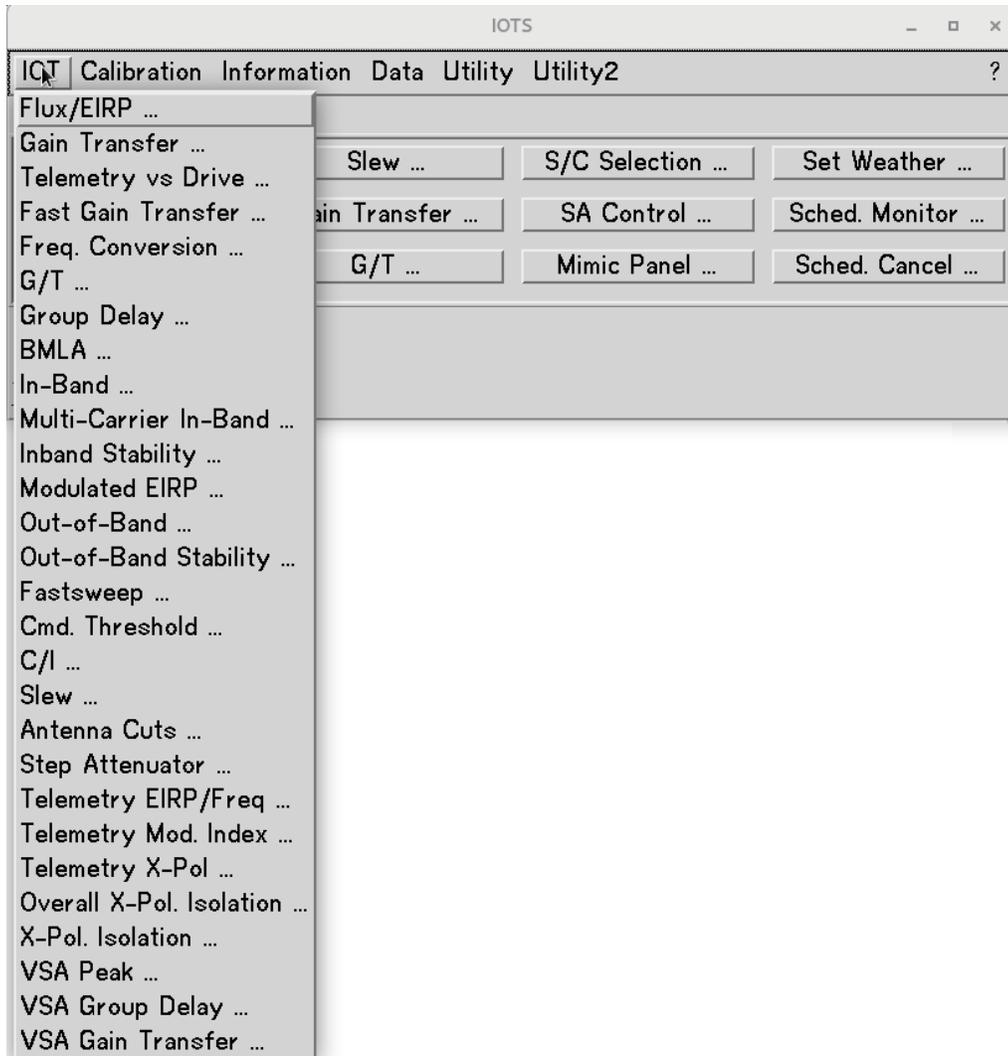
Figure 2-6 *IOT Measurements Menu*

The last item is one of the strongest features of the *Standard IOT System*. It allows the user to control the time and frequency of the measurement. It is this features that allow stability measurements. This scheduling coupled with multitasking is extremely useful for both routine operations and for anomaly investigations.

The spacecraft shown in the window of Figure 2-7 is D1. Let us assume that we want to perform the Frequency Response measurement on D2. To change the parameters shown in the Spacecraft panel we click on the "Update" button.

A new window appears which allows the user to select a spacecraft and spacecraft-related parameters. This window is shown on Figure 2-8 on page 2-9.

2.3.4   Spacecraft Selection Window

The Spacecraft selection window consists of several areas:

- the S/C selection menu

- the Beams panel

- the Receiver panel

- the Orbital panel

- the Channel panel
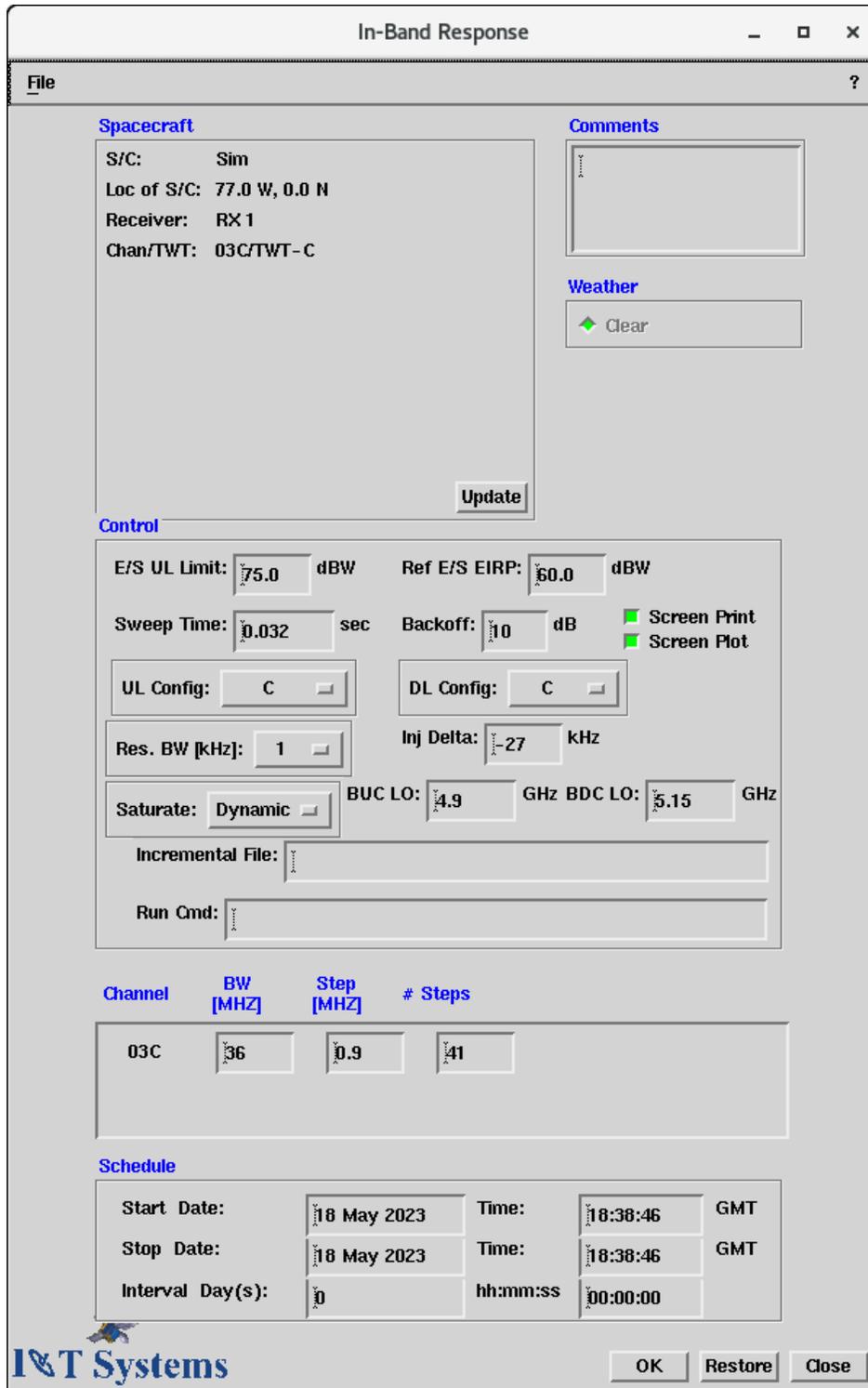
Figure 2-7 *Frequency Response Window*

Figure 2-8 *S/C Selection window*

The default values shown on all the panels depend on the actual spacecraft selected. These parameters are contained in editable spacecraft configuration files and can be modified or augmented without any programmatic changes. The Spacecraft selection windows are completely data driven.

As mentioned above we want spacecraft D2 instead of D1. So, we select it from the S/C selection menu as shown in Figure 2-9.

After we choose D2, all the values of the original Spacecraft selection window change. We notice that the Beams panel indicates that the receive beam is "Castle Rock" and the transmit beam is "CONUS". However, we want both beams to be "CONUS".

We can change the spacecraft beam configuration by clicking on the "Update" button on the Beams panel. A temporary window pops up as shown in Figure 2-10 on page 2-10.

We click on the "CONUS" radio button on the "Rx Beam" panel. As we do so we notice that the "Castle Rock" button is dimmed on the "Tx Beam" panel. This indicates that the "CONUS" receive beam can only be connected to the "CONUS" transmit beam. This behavior of the user interface is completely data driven and specific to an individual spacecraft.
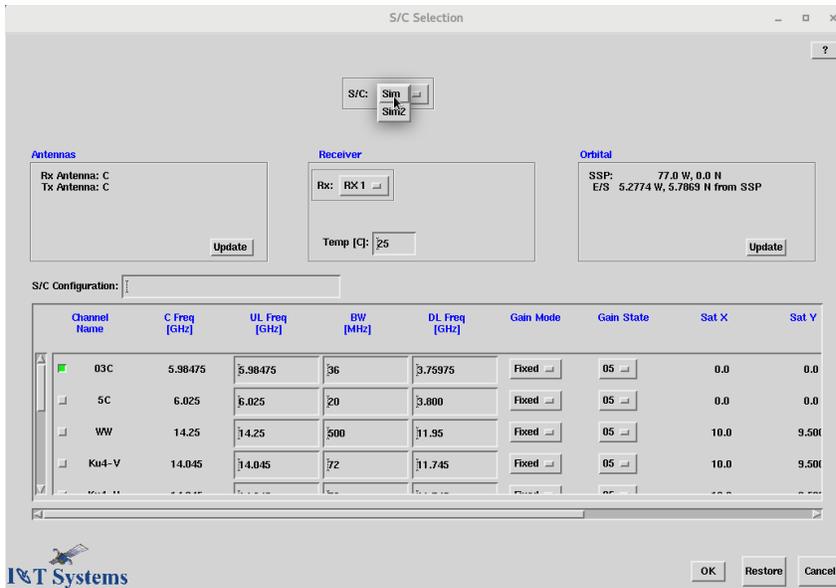
Figure 2-9 *S/C Selection menu*
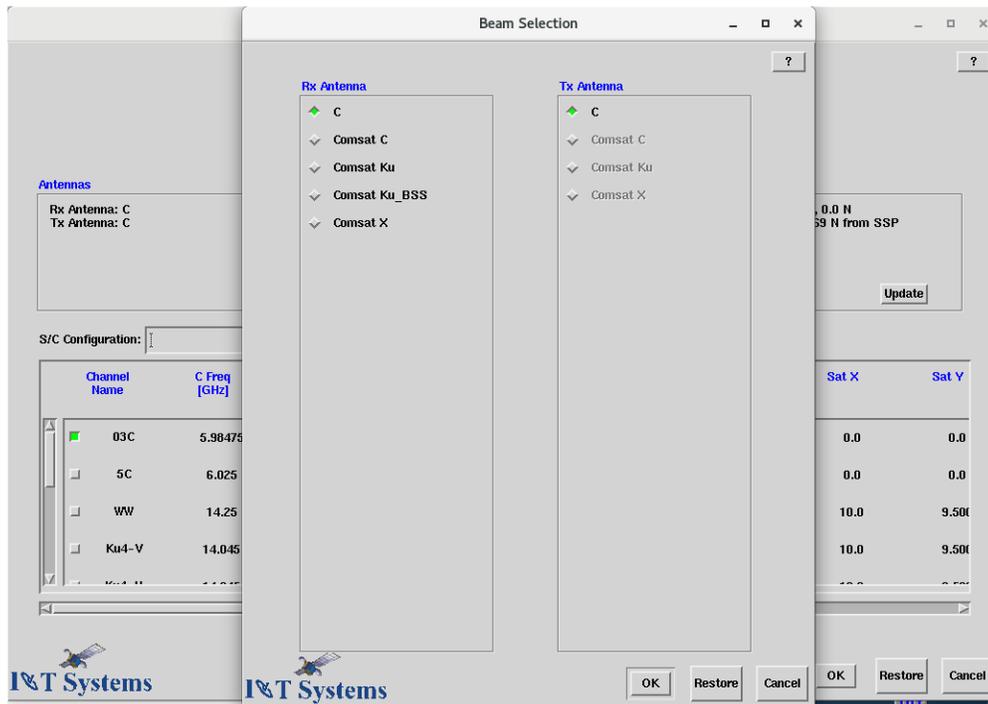
Figure 2-10 *S/C Beam Selection*

After we have selected the beam configuration, we click the "OK" button. The original Spacecraft selection window is updated. It now shows all the channels which are compatible with the selected receive and transmit beams.

The channels available for measurement are shown in a scrolling sub-window in the channel panel. The user can either accept all of them with their default values or he/she can select a

subset with modified values. Figure 2-11 shows that the user has selected channel 23, 25, and 27 and is changing the tube for 27.
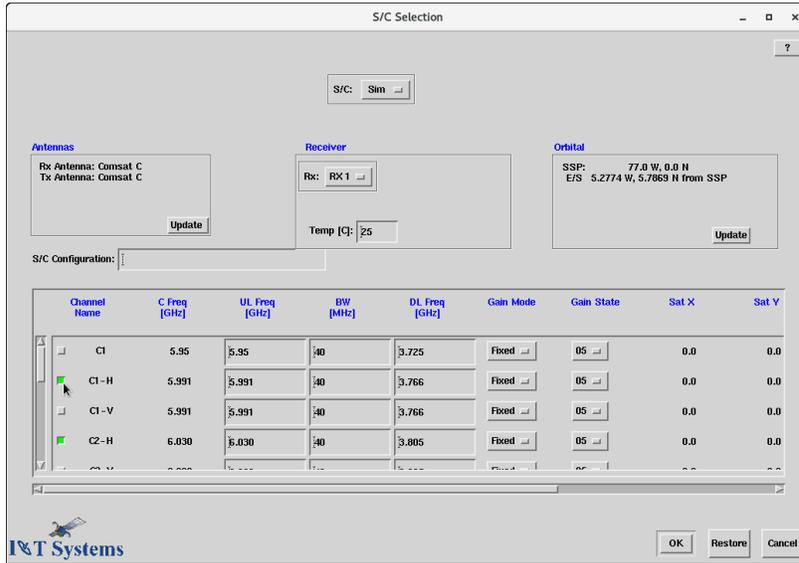
Figure 2-11 *S/C Window - Channel Selection*

Finally, once all the spacecraft parameters have been selected, we click on the "OK" button of the Spacecraft selection window. Now the Frequency Response window is updated to reflect the new spacecraft choices. Again, the channel panel of the Frequency Response window proposes default measurement parameters. For channel C1-H, for example, a measurement bandwidth of 40 MHz with 40 steps of 1 MHz each is proposed. The user can override these defaults, but the software checks any new values for being realistic and consistent with the rest. Here we select the "Step" value for channel C-1H and edit it from "1.00" to "1000". This clearly is a wrong value because 40 steps at 1000 MHz each will exceed the 40 MHz bandwidth. The system rejects this value and pops up a small dialog window informing the user of the reason for the rejection and states the valid range. This situation is shown on Figure 2-12.

Once the user has set or accepted the defaults of all the controls for the measurement, including scheduling information he/she clicks on the "OK" button of Frequency Response window. The IOT system then schedules the measurement. At the scheduled time, if the resources needed for the measurement are available, the actual measurement is executed.

2.3.5   Measurement Execution Status

When the measurement starts execution, it reads measurement control parameters, earth station calibration parameters, etc. All these data are stored in ASCII files which are accessible to the users for editing.

Execution of an automatic measurement procedure is performed either in the foreground (attended by the user) or in the background (unattended). In general the user decided at scheduling time whether the measurement is to be performed in the foreground or in the background. The semi-automatic measurements require user interaction *during* measurement execution and are always performed in the foreground.
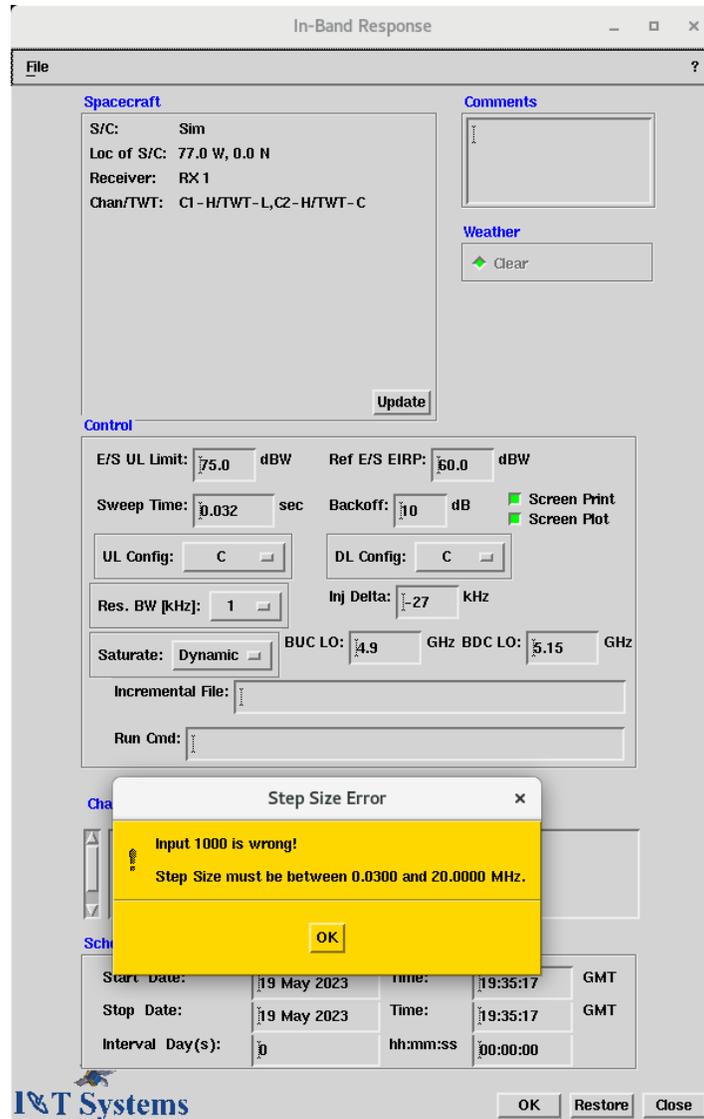
Figure 2-12 *Frequency Response - Warning*

During the foreground execution of a program, a Status window is displayed that reports on the execution status i.e. what the program is doing. Figure 2-13 on page 2-13 shows the status window for a Frequency Response measurement. The status is indicated by highlighting the current activity. The user can always close this window by clicking on the "Close" button. In addition he/she can set all the instruments to local mode, cancel, or pause the measurement by pressing the corresponding button. Pausing a measurement allows the user to proceed in a "step-by-step" fashion for troubleshooting purposes.

To maintain data integrity, measured data is stored in temporary files. At the completion of a foreground measurement the user is prompted for permanent data storage. Background measurements are always stored.

During measurement initialization, each instrument to be used by the measurement is checked for proper operation. If, during this phase, an instrument is not behaving correctly, or during

Standard IOT System • 2-13
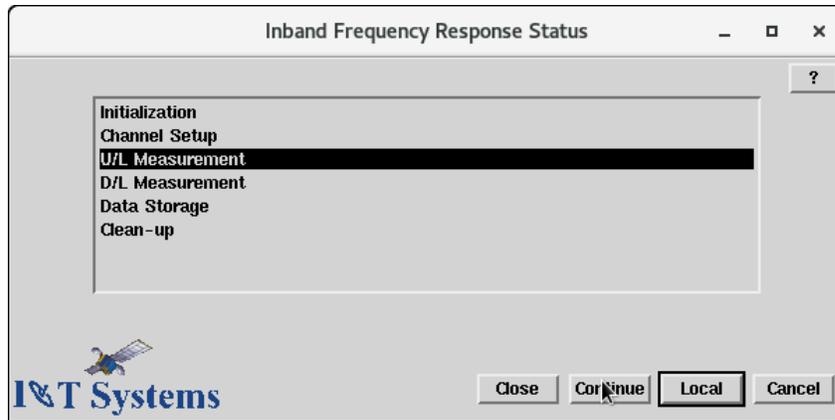
Figure 2-13 *Measurement Status Window*

the course of the measurement, there is an abnormal condition, the user is informed by means of an Error Dialog such as the one shown Figure 2-14 on page 2-13.

2.3.6 Error Reporting Dialog

The sometimes the Error dialog allows the user to either "Cancel" the measurement, "Repeat" the whole measurement sequence, or "Try Again" the failed operation. The last two choices are offered in case the user can remove the cause of the problem. For example, if an instrument does not respond,
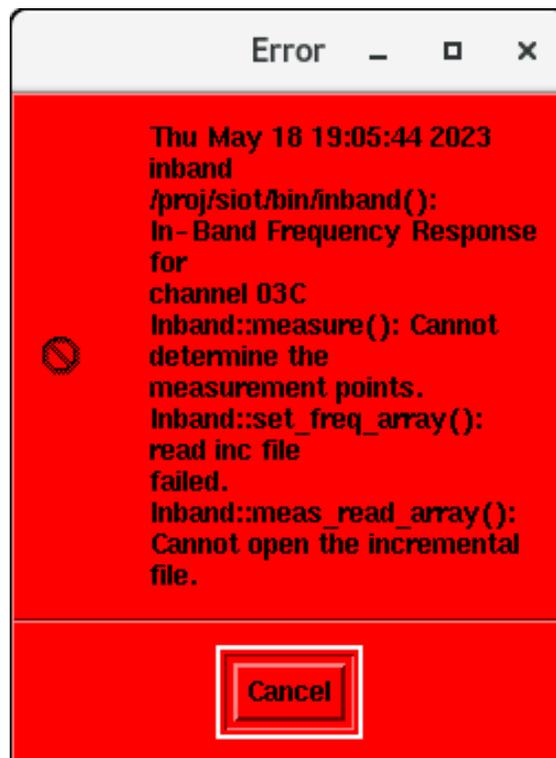
Figure 2-14 Measurement Error Window

instead of aborting a program, the user will click on the "Try Again" button.

If the user has an error that is not recoverable (like in this case) and/or cancels a measurement by so responding to an error dialog or if the measurement is canceled due to an unrecoverable error during background execution, the cause of the error is logged, together with the time, date, and program path to the actual line of code where the error was detected. The software keeps these logs in ASCII files which can be reviewed later. The corresponding error log entry is below.

2.3.7. Error Log Entry

In this error that is written to the error log, both in the dialog above and the error log entry you will see 4 error messages, one for each layer of software. The error system often shows many layers with information at each layer. The lowest level error is at the bottom, "Cannot open the incremental file" (because it is not there intentionally), "read inc file failed" and the top-level error "Cannot determine measurement points" (because they were to be derived from the incremental file), and at the very top is just what measurement was being executed.

```
1 >    Thu May 18 19:05:44 2023    inband  ?    23588
2 Error:   20    1    1    File:    meas_err.C    Line:    87    Time:    May 18 19:05
3    /proj/siot/bin/inband(): In–Band Frequency Response for channel 03C
4 Error:   20    1    1    File:    inband_lib.C    Line:    503    Time:    May 18 19:05
5    Inband::measure(): Cannot determine the measurement points.
6 Error:   20    1    1    File:    inband_lib.C    Line:    374    Time:    May 18 19:05
7    Inband::set_freq_array(): read inc file failed.
8 Error:   20    1    1    File:    inband_lib.C    Line:    389    Time:    May 18 19:05
9    Inband::meas_read_array(): Cannot open the incremental file.
~
~
```

Figure 2-15 Measurement Error Log Entry

2.3.8   Calibration and Information Menus

Let us now return to the IOT control window and explore some other IOT functions. If we click on "Calibration" on the menu bar near the top of the window, the window (Figure 2-15) shows us the full range of Calibration procedures available on the IOT. The first four menu items - Spectrum Analyzer Calibration, Power Meter Calibration, Zero Uplink Power Meters, and Zero Downlink Power Meters - are available with the *Standard IOT System*. The last two menu items are Verify Uplink Calibration and Verify Downlink Calibration.
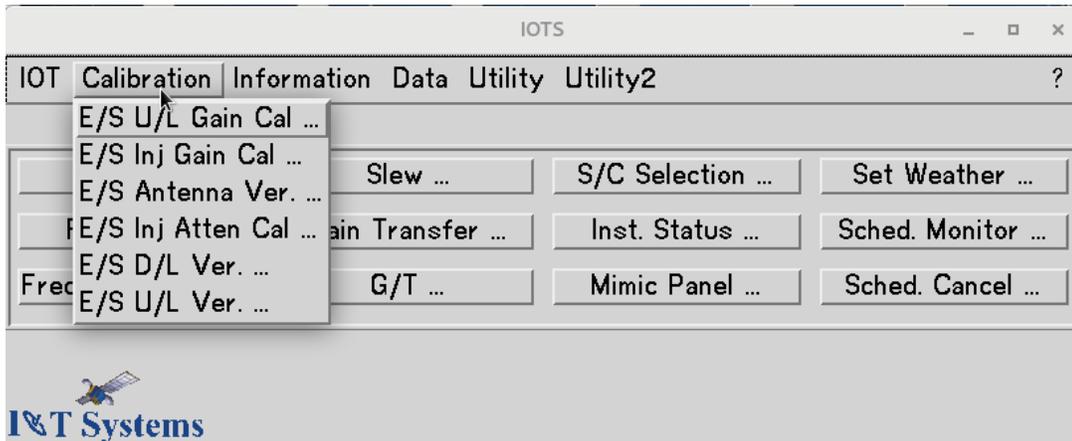
Figure 2-16 *IOT Calibration Menu*

The calibration data is stored in user editable ASCII files.

The "Information" menu of the IOT control window allows the user to access two windows which provide information on the current spacecraft configuration and its orbital characteristics.

2.3.9   IOT Database

The "Data" menu of the IOT control window (shown on Figure 2-16 on page 2-15) provides data file management utilities for finding, printing, plotting, and deleting data files.

Data files are kept in the IOT database. The database can be accessed either by specifying the name of a file or it can be searched to extract a file that meets certain search criteria. This search function is invoked via the "Db Search" menu of Figure 2-16.

Figure 2-17 on page 2-15 shows the database search form. The form allows the user to narrow the database search by specifying search criteria. All criteria are optional. In our example the user wants to find all data files for the D1 spacecraft, which contain measurements for channel "05" obtained up to January 8, 1993. By pressing the "Display" button all the file names that match the search will be listed on the workstation window. By pressing the "Print" button a similar list will be sent to the laser printer. By omitting all criteria other than the "Date From" and the "Date To", a user can obtain a report on all the measurements performed during a given calendar period.
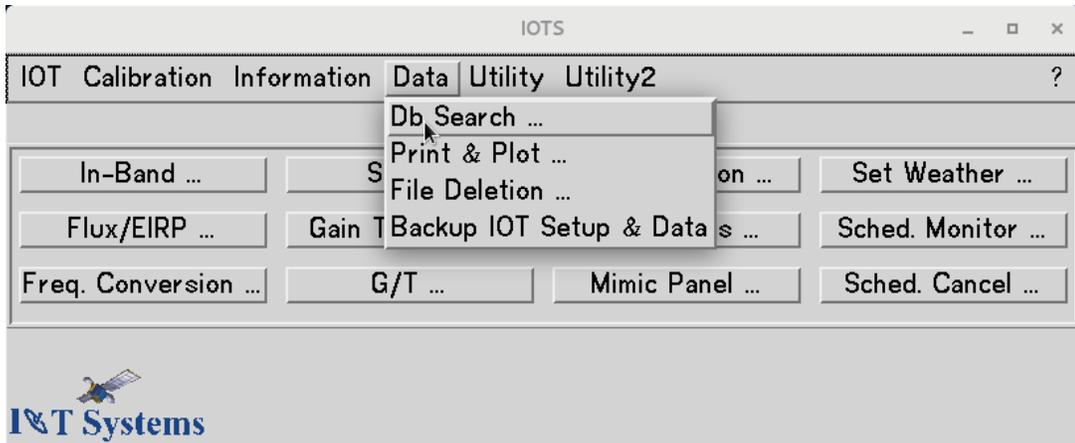
Figure 2-17 *IOT Data Menu*

Figure 2-18 *Database Search Form*

2.3.10   Typical Reports

A typical data file screen printout (tabular form) is shown on Figure 2-18 on page 2-16. This printout is from actual test data for an In-Band Frequency Response. The style of the printout is very flexible, and it is specified by a user-editable style file. The name of this style file as well as the name of the file which contains the original IOT data are printed on the lower right corner of the printout. The data can be displayed on the workstation, printed with *a PostScript® printer (laser)*, printed by a normal ASCII printer (the software formats it), or exported to other applications such as spreadsheets, word processors, mathematical packages, etc.

```
                          inbd857                        _  □  ×

                                                            ?

                    In-Band Frequency Response


                 SC: COMSAT
                 Date: 16 Oct 2007 23:35 GMT
                 Loc. of SC: 47.5 W, 0
                 Rx: B
                 Chan: 10C
                 HPA: 10
                 Saturate: No
                 Weather: Clear
                 Comment:

      Boff=0.00 [dB]


----------------------------------------------------------------------------
|UL Freq|DL Freq|  Pup | Pinj |   SA  |   SF  | UL Atm| DL PL | DL Atm|   IPFD   | EIRP |  Gain |
| [GHz] | [GHz] | [dBm]| [dBm]|  [dB] |[dBm^2]|  [dB] |  [dB] |  [dB] |[dBW/m^2]| [dBW] |  [dB] |
|----------------------------------------------------------------------------|
| 6.1725| 3.9475|-29.91|-31.45| -50.73| 162.62|   0.07| 196.01|   0.06| -117.35 | -37.05| 117.56|
| 6.1735| 3.9485|-29.90|-32.82| -37.38| 162.62|   0.07| 196.01|   0.06| -117.34 | -25.07| 129.53|
| 6.1745| 3.9495|-29.84|-31.69| -29.52| 162.62|   0.07| 196.01|   0.06| -117.28 | -16.09| 138.45|
| 6.1755| 3.9505|-29.89|-31.66| -25.82| 162.62|   0.07| 196.01|   0.06| -117.32 | -12.35| 142.24|
```

I&T Systems   [Close]   [Pause]   [Local]   [Cancel]

Figure 2-19 *Typical Data File Screen Printout*

In addition to obtaining a printout, a user can plot the data (graphical form) of an IOT file and either display the plot on the workstation, plot it with an HPGL pen-plotter, print it with a *PostScript*® Laser printer, or export it to other applications such as word processors. A specification mask can be superimposed on any plot. The IOT maintains a database of such specification masks organized by S/C, and channel and automatically selects the mask to be superimposed on the measured data. These masks are a useful aid in data evaluation.

A plot of actual IOT data obtained from frequency response measurements is shown in Figure 2-19 on page 2-17. As in the case of the printout, the details of the plot are dictated by an editable style file. The name of this style file, the specification mask file, as well as the name of the file which contains the original IOT data, are printed on the lower right corner of the plot. The *Standard IOT System* is capable of plotting data in a very rich repertory of styles.

The stylistic details of the reports will be decided in cooperation with the customer prior to the IOT.

Inband Frequency Response of Channel 10C

Gain [dB] Offset: 146

Legend: Gain —— Gain Min ----- Gain Max -----

SC: COMSAT
Date: 16 Oct 2007 23:35 GMT
Loc. of SC: 47.5 W, 0
RX: B
Chan: 10C
HPA: 10
Saturate: No
Earth Station(s): Clarksburg
Weather: Clear
Boff: 0.00 [dB]

Freq [GHz] Center Freq: 6.205

SOURCE FILE: inbd857
STYLE FILE: inband.pls
MASK FILE: inband36.msk

I&T Systems

Figure 2-20 *Typical Data File Plot*

2.3.11 Utility Menu

The next menu of the IOT control window is the "Utility" menu and is shown in Figure 2-20 on page 2-18. This menu allows the user to invoke several utilities: The Mimic Panel (described in a later section), the system error logs, and the Scheduler.
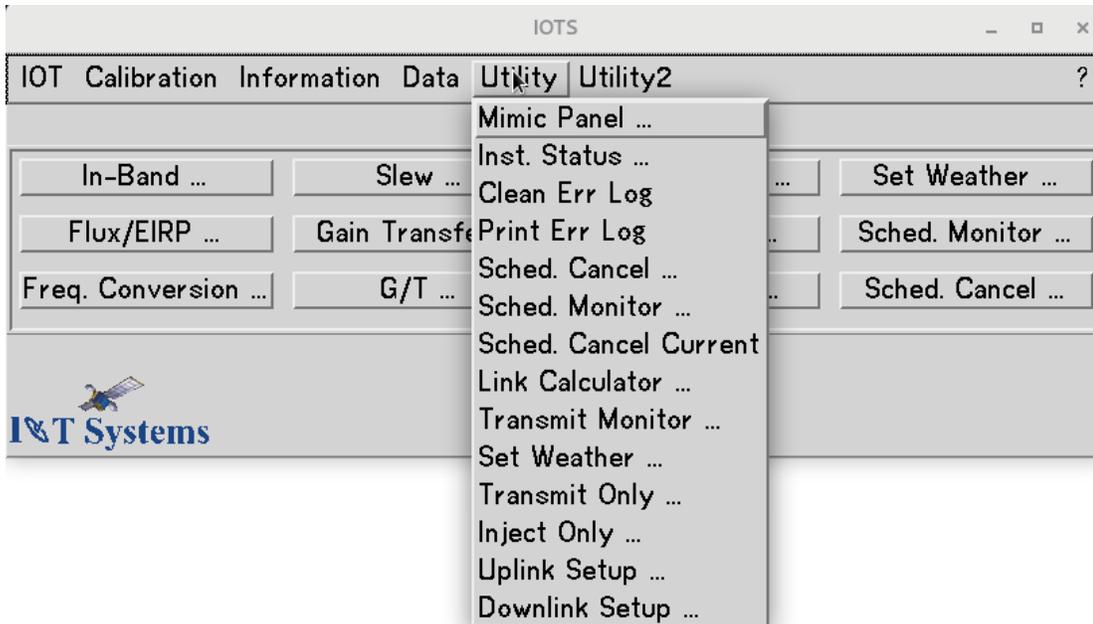
Figure 2-21 *IOT Utility Menu*

During the operation of the IOT any unexpected events (instrumentation errors, alarms, etc.) are logged in a special error directory. These error logs are an invaluable tool for troubleshooting the IOT and other earth station related problems. The error utilities allow the user to get a hardcopy printout of these logs and to erase old logs.

Inband Frequency Response of Channel 10C

Gain [dB] Offset: 146

Legend: — Gain ---- Gain Min ---- Gain Max

SC: COMSAT
Date: 16 Oct 2007 23:35 GMT
Loc. of SC: 47.5 W, 0
RX: B
Chan: 10C
HPA: 10
Saturate: No
Earth Station(s): Clarksburg
Weather: Clear
Boff: 0.00 [dB]

Freq [GHz] Center Freq: 6.205

I&T Systems
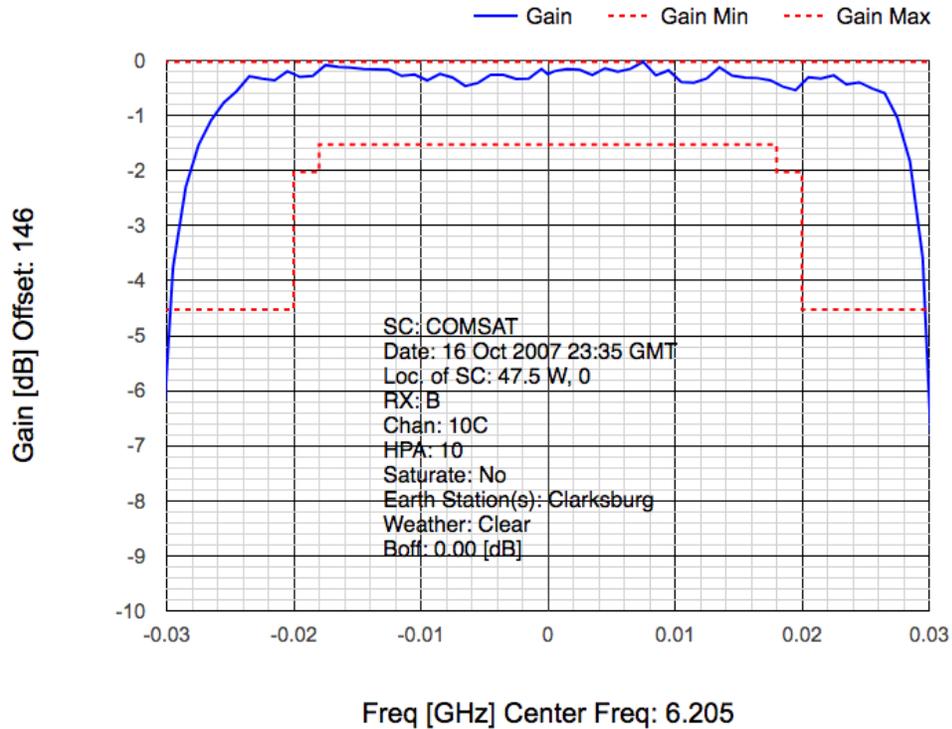
SOURCE FILE: inbd857
STYLE FILE: inband.pls
MASK FILE: inband36.msk

Figure 2-22 *Typical Data File Plot*

2.3.12 Utility2 Menu

The next menu of the IOT control window is the "Utility2" menu and is shown in Figure 2-20 on page 2-18. This menu allows the user to perform a manual check-out of an instrument which will pause any new automated measurements from being scheduled and using that instrument.
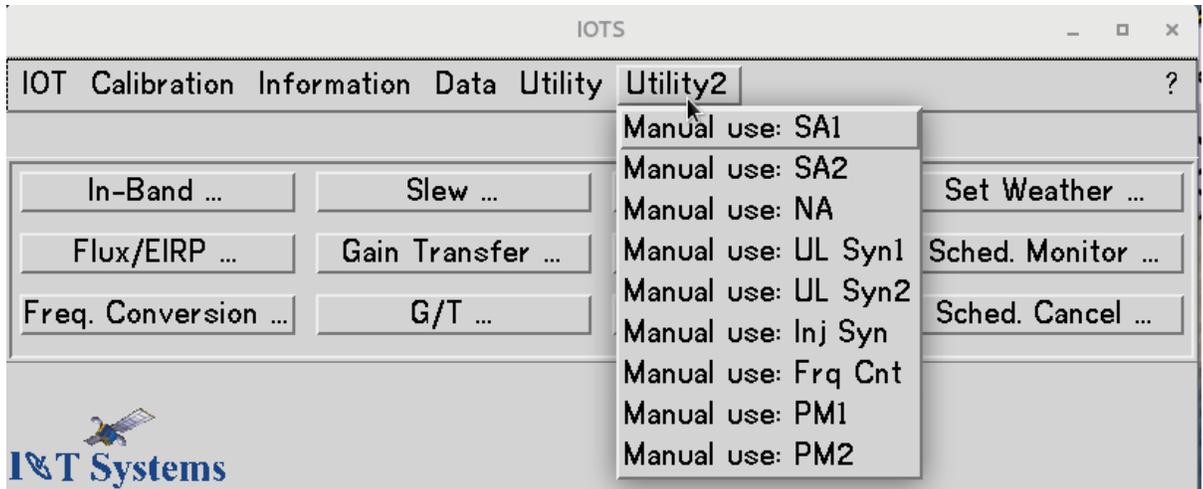
Figure 2-23 *IOT Utility2 Menu*

2.3.13 Link Calculator

The IOT Link Calculator is a useful tool for looking at various levels in the system based on the calibration files. We can set the U/L Synthesizer to a frequency and power and see what the expected power meter reading and expected U/L EIRP. On the downlink we could set the expected EIRP and see what the inject power meter and spectrum analyzer should read if the signal is matched.

Figure 2-24 *IOT Link Calculator*

2.3.14 Error Logs

The error logs are an invaluable tool for measurements, equipment, and other earth station related problems.

There is a separate error log for each measurement and the In-Band error log and is shown in Figure 2-20 on page 2-18. There are 4 levels to this particular error. Top level is the Measurement, the next level is from trying to calculate the frequency points for measurement, the next level is unable to read the file for the frequency points, and the last is unable to open the file.

```
1 >    Thu May 18 19:05:44 2023    inband  ?   23588
2 Error:   20   1   1    File:    meas_err.C   Line:    87   Time:    May 18 19:05
3     /proj/siot/bin/inband(): In—Band Frequency Response for channel 03C
4 Error:   20   1   1    File:    inband_lib.C   Line:   503   Time:    May 18 19:05
5     Inband::measure(): Cannot determine the measurement points.
6 Error:   20   1   1    File:    inband_lib.C   Line:   374   Time:    May 18 19:05
7     Inband::set_freq_array(): read inc file failed.
8 Error:   20   1   1    File:    inband_lib.C   Line:   389   Time:    May 18 19:05
9     Inband::meas_read_array(): Cannot open the incremental file.
~
~
```
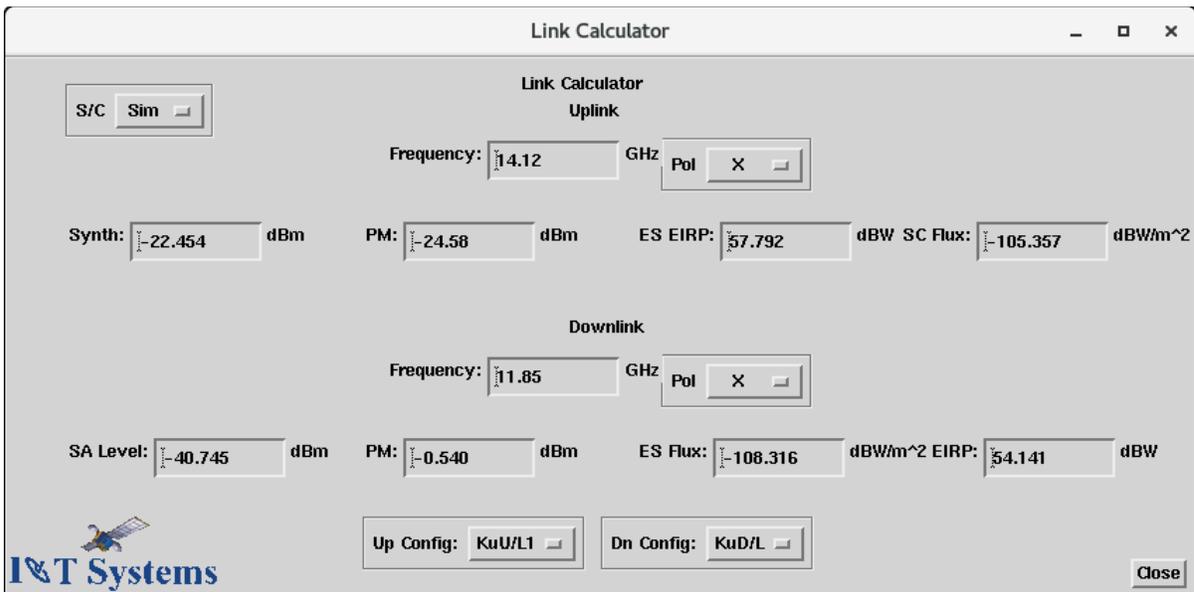
Figure 2-36 *In-Band Error Log*

2.3.15 Atom Files

Atom files contain all the arguments and other parameters required

for a specific measurement.

Figure 2-37 shows a directory of atom files on the Linux system.

To open an atom file the user right clicks the icon and selects the program to open that file, and in many cases if this type of file has been opened recently, just double click and open the MUI for that measurement, the user can then schedule the measurement by pressing OK in the MUI. There is another way, right click, select **Schedule Now**, and the measurement is scheduled immediately. This is an extremely powerful feature.
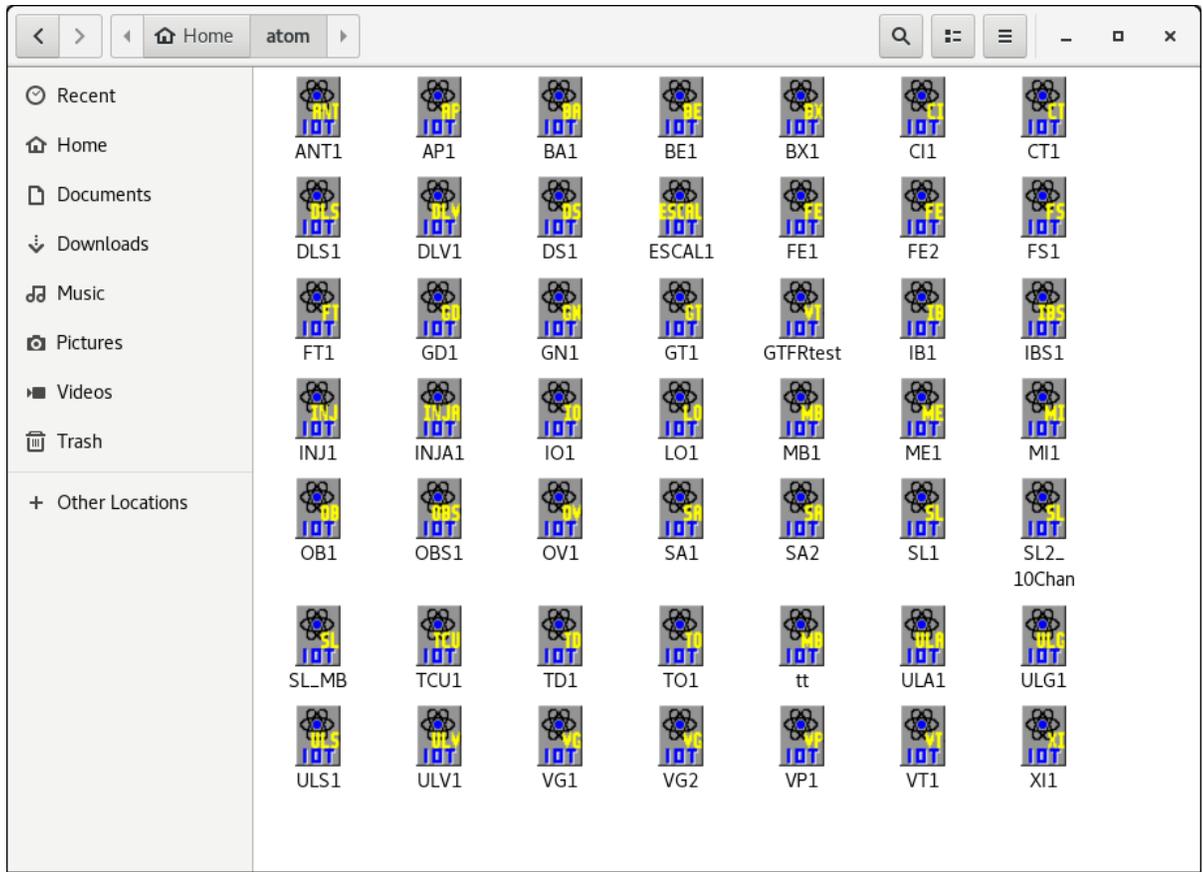
Figure 2-37 *Atom File Folder*

2.3.17 Additional Features

It is nearly impossible to relate the full capability available to the user. Basically everything we could think of is included in the *Standard IOT System*.

2.4 Software Testing

The IOT uses existing *Standard IOT System* software which has been extensively tested both in the laboratory and in the field and has tested over 100 satellites.

All new software will be tested prior to system delivery, either with the actual instrumentation or by means of either hardware or software simulators.

2.5 Software Documentation

IOT Systems software code is well documented and adheres to internally developed software standards and styles.

2.6 Software Backup

UNIX scripts will be provided for reliable software and data backup to a removable medium. In the case of total destruction of the hard disk the user will be able to recreate the IOT environment, as of the last backup, on a new hard disk.

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Section 3

Standard IOT System

3.1 *Standard IOT System* Offering

3.1.1 Description

IOT Systems offers a fully developed, fully tested, Commercial-off-the-shelf (COTS) *Standard IOT System* for performing in-orbit testing (IOT) following the successful launch of a communications satellite; for investigating anomalies of operational spacecraft; and for monitoring the communications subsystem and traffic. Because of its flexible, expandable system design, the *Standard IOT System* can be readily customized to meet specific Customer requirements. Optional capabilities can be added to enhance or expand the system's capabilities. The *Standard IOT System* purchase can be initiated by contacting Steve Teller, President of IOT Systems via email at teller@iotsystems.com and follow up with a call at +1 301-892-6256 and please leave a message, we get a lot of spam calls.

For additional information concerning our *Standard IOT System*, contact:
Steve Teller, President of IOT Systems, Hagerstown Maryland 21742 (in U.S.A).
Telephone: (301) 892-6256 or by Fax: (651) 691-2940 (all in the U.S.A.), Email: teller@iotsystems.com

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The *Standard IOT System* performs IOT measurements using a suite of calibrated microwave measurement equipment under the control of a multiuser, multitasking UNIX based computer. The *Standard IOT System* uses commercial-quality microwave equipment and IOT Systems-developed and owned software to perform a suite of IOT measurements. The operator controls measurements via graphically based X Windows displayed on the color monitor, the mouse, and the keyboard. The mouse permits the user to select items in a window by "pointing-and-clicking" at menus on the display. The displayed windows are implemented with the Open Software Foundation's OSF/Motif toolkit and user interface style guidelines. The *Standard IOT System* displays measurement results as tabular data on the monitor as well as printing hardcopy tabular reports on the laser printer. Many measurements also produce hardcopy plots on the laser printer. The *System*'s human interface is easy to use by the non-expert, while retaining flexibility and easily accessed power for the more experienced user.

Because it is an off-the-shelf, field-tested system, the *Standard IOT System* can be delivered to a Customer very quickly, requiring only assembly and integration of the microwave and computer equipment prior to its installation and testing at the Customer's earth station. IOT Systems will assemble, install, test, and deliver the Commercial-Off-The-Shelf(COTS), *Standard IOT System* in six (6) months after receipt of order if IOT Systems purchases the microwave and computer equipment, or in three (3) months after receipt of all equipment.

IOT Systems' IOT systems are built using Linux based systems and mostly Keysight measurement hardware, thereby providing a worldwide support organization, and equipment with recognized high reliability and performance characteristics. The selection of Keysight equipment for measurement equipment ensures integrated IEEE-488 compatibility from the company that originally developed the programmable instrumentation bus standard.

Our IOT systems are controlled by the Linux Operating System, which comply with XOpen and POSIX specifications. The workstation supports the IEEE 802.3/Ethernet local area network(LAN) and the TCP/IP protocol.

The *Standard IOT System* is a Commercial-Off The-Shelf(COTS) product: the design and IOT Systems-developed software have already been developed and tested. New system installation is merely a matter of procuring the microwave equipment and assembling, integrating, and installing the system equipment at the Customer's site after receipt of an order.

Although the *Standard IOT System* is offered as "Commercial-Off The-Shelf", certain aspects of the *System*'s design are very flexible and can be readily and quickly customized to meet specific Customer requirements by IOT Systems or by the customer. In particular, the style and formatting of print and plot outputs are readily customizable. The number of antennas, the test equipment, many things are very customizable by IOT Systems, or by the customer.

The *Standard IOT System* operates over a single Customer-specified frequency band from L-Band to Ka-Band. Additional frequency bands can be accommodated. The *Standard IOT System* measures signal power levels over a dynamic range of 35 dB measured at the feed of the earth station antenna, subject to the noise floor of the earth station. The dynamic range can be optionally extended to as much as 105 dB, subject to the noise floor of the earth station. The *Standard IOT System* supports dual-polarization uplink and downlink transmissions.
When ordered, the *Standard IOT System* is tuned to operate with the Customer's specific spacecraft transponder frequency plan, topology, and connectivity, and this tuning is included in *Standard IOT System* price.

3.1.2   IOT Measurements

The *Standard IOT System* performs the measurements shown in Table 3-1 on page 3-2 & page 3-3.

Measurement	Accuracy [a]	Time [b](secs)
Spacecraft (S/C) e.i.r.p. [c]	0.5 dB	1.3 sec/point
S/C e.i.r.p. stability	0.23 dB/24 hrs.	1.3 sec/point
S/C i.p.f.d. [d]	0.52 dB	1.3 sec/point
S/C i.p.f.d. stability	0.23 dB/24 hrs.	1.3 sec/point
TWTA saturation point	0.1 dB	30 secs

Table 3-1   Standard IOT System Measurements

Measurement	Accuracy [a]	Time [b] (secs)
In-band frequency response and stability	0.13 dB (at saturation)	2.6 sec/point
Out-of-band frequency response and stability	0.13 dB (saturation)	2.6 sec/point
Fastsweep frequency response	0.27 dB (linear)	30 sec/40 MHz
S/C Receive antenna patterns	0.5 dB	1.3 sec/point
S/C Transmit antenna patterns	0.11 dB	1.3 sec/point
Rx antenna cross-pol isolation pattern	+2.27/-2.97 dB	1.3 sec/point
Tx antenna cross-pol isolation pattern	+2.54/-3.38 dB	1.3 sec/point
S/C frequency conversion error	586 Hz	2.6 sec/point
S/C frequency conversion error stability	3.15 Hz	2.6 sec/point
Gain transfer	0.65 dB	2.6 sec/point
Fast Gain Transfer	0.65 dB	10 sec
Gain-to-noise temperature (G/T)	0.54 dB	2.6 sec (gain)
Gain-to-noise temperature stability	0.27 dB	2.6 sec (gain)
Gain adjustment (S/C attenuators)	0.21 dB (linear)	2.6 sec/point
Spurious output	0.5 dB	depends on bandwidth
Beacon e.i.r.p [e]	0.5 dB	1.3 sec/point
Beacon e.i.r.p stability	0.23 dB/ 24 hours	1.3 sec/point
Beacon frequency [f]	3110 Hz	1.3 sec/point
Beacon frequency stability	3.15 Hz/24 hours	1.3 sec/point
Beacon cross-polarization isolation	+2.27/-2.97 dB	2.6 sec
Spectrum analyzer monitoring [g]	N/A	N/A

Table 3-1 (cont.)   Standard IOT System Measurements

a. measurement accuracies are referenced at the output of the Customer-supplied couplers (two couplers after the HPAs on the uplink, two couplers before the LNAs on the downlink). Accuracy values are stated in "RSS" or "Root Sum Square", unless otherwise indicated. b. measurements times are typical values.
c. e.i.r.p is "effective isotropic radiated power".
d. i.pf.d. is "input power flux density".
e. can also be used for TT&C measurements, e.g. "Command Threshold", etc.
f. can also be used for TT&C measurements.

g. spectrum analyzer monitoring can produce hardcopy plots of the analyzer's display, can display its output on a remote CRT, and can also be set up from a remote CRT.

3.1.3 Standard IOT System User Interface Window Customization

Certain aspects of the *Standard IOT System* implementation are customizable to a Customer's requirements and these customizations are included within the *Standard IOT System* offering. Additional customization as may be required by a particular Customer and can be accommodated but are not included as part of the *Standard IOT System* offering.

The *Standard IOT System* offering includes customization of the spacecraft selection and configuration window and print and plot formats as follows.

The spacecraft configuration window enables the user to specify the spacecraft and test configuration of the spacecraft to be tested. The *Standard IOT System* spacecraft selection and configuration window contains these components:

1. Spacecraft selection of a particular spacecraft for testing:

    The names of the individual spacecraft displayed in a pulldown menu and the number of spacecrafts in the menu is customized as part of the *Standard IOT System* offering.

2. Selection of receive and transmit antenna beams:

    The names of receive beams and transmit beams displayed in a menu and their connectivity combinations is customized as part of the *Standard IOT System* offering. For example, a particular receive beam may connect to certain transmit antenna beams but not to others.

3. Selection of a receiver and its gain and temperature:

    The names of the spacecraft's receivers, their gain values, and the default receiver temperature is customized as part of the *Standard IOT System* offering. The temperature is a user-editable field.

4. Orbital information consisting of subsatellite point (SSP) and earth station coordinates from the SSP:

    The default values displayed in the "Orbital" window for the earth station latitude and longitude and the spacecraft's latitude and longitude is customized as part of the *Standard IOT System* offering. The "Orbital" window in the *Standard IOT System* calculates the earth station position referenced to the subsatellite point, the range from the earth station to the spacecraft and the spreading factor.

5. Channel selection for measurement and channel parameters as follows:

    The following information is customized in the spacecraft selection and configuration window on a per-channel basis:

    a) name of the channel and whether it is selected for test or not.

b) the default displayed value of the channel center frequency, uplink frequency, downlink frequency, and bandwidth; these are user-editable fields.

c) the transponder control unit (TCU) names, modes and states displayed in a pulldown menu.

d) the number and names of the limiter/linearizer states displayed in a pulldown menu.

e) the number and names of the TWT states displayed in a pulldown menu.

f) the number and names of channel power level states displayed in a pulldown menu.

g) the default displayed value of the "y/x" saturation value; this is a user-editable field.

The *Standard IOT System* offering includes customization of the number of the items and their names displayed in pulldown menu components of the spacecraft selection and configuration window and the default displayed values of user-editable fields. These customizations conform to the underlying model of the spacecraft included in the *Standard IOT System* offering. However, changing the model of the spacecraft, such as adding new components not currently implemented in the *Standard IOT System* offering or deleting non-applicable components, is not within the scope of customization offered as part of the *Standard IOT System* but can be accommodated as Customer-mandated requirements (refer to subsection 3.4 on page 3-17).

Customization of other *Standard IOT System* windows is not included in the *Standard IOT System* offering.

The spacecraft selection and configuration window customization included with the *Standard IOT System* offering are carried through to the measurement user interface windows and to the plots and printouts.

3.1.4 Standard IOT System Output Customization

Because the *Standard IOT System* printout and plot form IOT are determined by static ASCII style files, some customization of print and plot form IOT is included with the *Standard IOT System* offering and these are described below.

When IOT measurements are performed, the resulting data is stored in a measurement data file containing various measured quantities (e.g., the uplink and inject power meter readings), stored calibration quantities (e.g., antenna gain, uplink and downlink calibrated coupler values), computed quantities (e.g., input power flux density, effective isotropic radiated power, GMT time). Each type of IOT measurement stores raw and processed data as appropriate for that measurement.

The tabular data displayed on the monitor during the measurement and hardcopy printed is a generally a subset of the data stored in the measurement data file. Because the format of softcopy printing to the monitor and the hardcopy printing of tabular measurement data to the

laser printer is controlled via static ASCII files, the customization included as part of the *Standard IOT System* offering includes the subset of measurement data to be printed and their ordering. Fonts are also customized within the range of available fonts as part of the *Standard IOT System* offering.

Hardcopy plot outputs are customized to the following extent as part of the *Standard IOT System* offering. The Customer can choose which quantities available in the measurement data file are to be plotted, the scales and labeling of the axes, whether a specification mask is to be plotted, whether or not a grid is to be plotted, and the specific information to be printed in the legend area of the plot from among the available information in the measurement data file.

Additional customization of print and plot formats can be accommodated per a Customer's specific requirements, but these customizations are not included in the *Standard IOT System* offering (see section 3.4 on page 3-17).

3.1.5   Technical Exchange Meeting

The *Standard IOT System* includes one (1) technical exchange meeting for two (2) days with the Customer's representative(s) to be held at IOT Systems in Hagerstown, MD (USA). This meeting is to be arranged shortly after receipt of order(ARO). We can also have the meeting virtually to reduce your cost and time.

3.1.6   Equipment Configuration

The *Standard IOT System* includes microwave measurement and computer equipment mounted in standard, 19-inch commercial quality equipment racks. The racks may be portable of fixed based on the customer needs.

3.1.7   Networking Capabilities

The *Standard IOT System* includes the capability of connecting to any X terminal or workstation supporting a standard IEEE 802.3 local area network (LAN). The software is compatible with the X Window environment and supports TCP/IP networking protocol.

The *Standard IOT System* can be remotely accessed and controlled from any location by the Customer's addition of network infrastructure

3.1.8   Environmental Requirements

The *Standard IOT System* offering assumes the following environmental conditions:

- AC Power: Single-phase power, 115/220 VAC
- Air-conditioned installation site with a false floor. If a false floor is not available, the equipment can be installed on a hard floor, but fans and an extra equipment rack are added at extra cost to the Customer.
- If the site is located in an earthquake zone, it will be necessary to bolt the equipment racks to the floor at extra cost to the Customer.

3.1.9   Site Survey, Installation and On-Site Testing

The *Standard IOT System* includes a site survey of the earth station and installation by IOT Systems personnel.

Installation of the waveguides and cable runs from the antenna feeds to the *Standard IOT System* equipment racks are the Customer's responsibility, and this installation is not included in the *Standard IOT System* price.

The *Standard IOT System* includes the conduct of a Site Acceptance Test (SAT) at the Customer's host earth station.

NOTE: The *Standard IOT System* price includes the labor for such on-site survey, installation, and the SAT. However, since the travel and per diem costs will vary dependent upon the location of the host Earth Station, these costs will be reimbursed separately from the *Standard IOT System* price based upon actual cost-plus G&A.

3.1.10   Training

The *Standard IOT System* includes sixteen (16) hours and tests on the Customer's spacecraft at the Customer's site. NOTE: The *Standard IOT System* price includes the labor for such training. However, since the travel and per diem costs will vary dependent upon the location of the Earth Station, such costs will be reimbursed in addition to the *Standard IOT System* price based upon actual cost plus G&A.

IOT Systems personnel will conduct the training while running tests on a Customer spacecraft at the installation site. The trainer or trainers will:

- present the system design and operation.
- demonstrate the power-up sequence of the system and the proper shutdown procedure for the system.
- demonstrate the operation and control of the installed measurements.
- describe and demonstrate the operation of the system's scheduler.
- describe and demonstrate the calibration functions.
- generate example print and plot outputs using the database feature.
- demonstrate other system features such as the Graphic Mimic Panel.
- describe maintenance and administration of the system including special system files and their location and purpose, and system backup and recovery procedures.
- answer questions.

3.1.11   Documentation

The *Standard IOT System* includes three documentation manuals: Administrator's Manual, User's Manual, Theory of Operation Manual as described below.

A User's Manual documents the usage and operation of the system. The user interface controls, and examples of the print and plot outputs are documented for each measurement. The use and operation of other system features, such as performing calibrations, performing database searches, using the Graphic Mimic Panel, and using the interactive data analysis program, are documented. System maintenance and administration procedures are also documented, such as the purpose and location of special system files and performing system backup and recovery procedures.

A Theory of Operation describes the methodology, an error analysis, the hardware configuration and equipment used, and the measurement's logical flow sequence for all the measurements.

Updates to the existing manuals and additional as built documentation available on a time & materials basis.

3.1.12 Warranty

IOT Systems warrants IOT Systems-supplied software and any IOT Systems-built hardware for one (1) year from the date of completion of the installation at the installed site.

This warranty covers all IOT Systems-developed software, such as measurements, user interface windows, and print and plot output, but it excludes software provided by a third party, such as the Red Hat Linux operating system.

IOT Systems' warranty obligations for non-IOTS- built equipment is based upon transferring all manufacturer's warranties to the Customer following installation and testing of such equipment.

IOT Systems will provide Keysight software updates to the Customer, provided that the Customer has separately entered into a software support agreement with Keysight.

Software excluded from this warranty provision is as follows:

- The RHE Linux operating system, bundled with and delivered with the workstation.
- internal measurement equipment software bundled with and sold as a part of the equipment, e.g. the instruments internal software.

3.1.13 Spares Recommendations

As all hardware used in the *Standard IOT System* offering is commercial, off-the-shelf equipment, a recommended spare parts list is not normally provided, as appropriate information is contained in the supplied Hardware Reference Manual.

However, if a Customer desires such a list of Recommended Spare Parts, it will be provided.

3.1.14 Hardware Support and Maintenance

Upon the expiration of microwave equipment and computer hardware warranties offered by the manufacturer with the equipment at purchase, IOT Systems strongly recommends that the Customer enter into separate hardware support and maintenance agreements with Hewlett-Packard for the microwave and computer equipment.

These support agreements with the equipment manufacturer provide support and maintenance services above and beyond the equipment warranties offered by the manufacturer.

Upon the expiration of IOT Systems' one-year warranty on the IOT Systems-developed software and any IOT Systems-built hardware, IOT Systems can enter a separately negotiated Extended Warranty with the Customer for IOT Systems-developed software and any IOT Systems-built hardware. An Extended Warranty (terms and conditions subject to negotiation) is not included in the *Standard IOT System*.

3.1.15 Other Representations

IOT Systems-supplied software is not reproducible, and license is not transferable.

Support and Maintenance Services for equipment can be supplied by the Keysight and the vendors of any other Major Equipment.

The following are not included in the *Standard IOT System*:

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- Customizing of IOT Systems' software or documentation to the Customer's specifications (available on a Time and Materials basis).
- Transportation costs. Transportation of equipment is F.O.B. IOT Systems, Hagerstown, Maryland (U.S.A). All other shipping costs will be extra charge.
- Travel Expenses and per diem to the Customer's earth station are not included in the *Standard IOT System*.

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Graphic Mimic Panel

4.1 Management Summary

- At a glance and in real time the operator can see graphically the current configuration of the earth station and IOT via the browser based Graphic Mimic Panel.

- The user can control the station configuration from the Graphic Mimic Panel.

- While the Graphic Mimic Panel monitors station configuration, the user can go to the "Edit" mode where, by pointing to a switch with the mouse and clicking on it, the user can propose a new switch position and station configuration.

- When the user is satisfied and instructs the Graphic Mimic Panel to "Set" the new configuration, the software automatically executes, confirms, and displays the new configuration.

4.2 Introduction

The Graphic Mimic Panel (GMP) is the primary switch control panel for the IOT user. The Switch control unit(s) are accessed from the GMP.

The user can change the state of any of the user-accessible RF switches by using the IOT Graphic Mimic Panel or manually at the equipment racks and antenna Hub. Although the GMP permits the user to change switch positions, generally, the IOT implements passive switch control. That is, the IOT does not throw hardware switches unless specifically requested by the user, permitting maximum user flexibility. The exception to passive control is when the IOT is performing IOT measurements. In this case the IOT commands the Switch Control Unit(s) to throw the appropriate switches to automatically configure and perform the measurements. To see the configuration of the system after the IOT automatically controls the switches from the automated measurements the User can select "Edit" then "Monitor" to see the updated positions. The Graphic Mimic Panel does not automatically update the positions unless directed by the user to prevent collisions with the automated measurements.

Figure 4-1 on page 4-2 shows a typical IOT Graphic Mimic Panel window.

The GMP consists of the primary "IOT Graphic Mimic Panel" and up to 8 sub-panels accessed from the primary panel(often not needed), additional subpanels can be added which are represented as box icons in the primary IOT GMP. The actual layout of the primary GMP panel as well as any required subpanels will be reviewed with the customer. The GMP can vary dramatically from installation to installation.

The GMP displays the following elements. The large central area schematically displays the current configuration of switches, or the proposed configuration if it is being edited. The bottom right area of the panel contains four pushbuttons to control the mode of the panel.
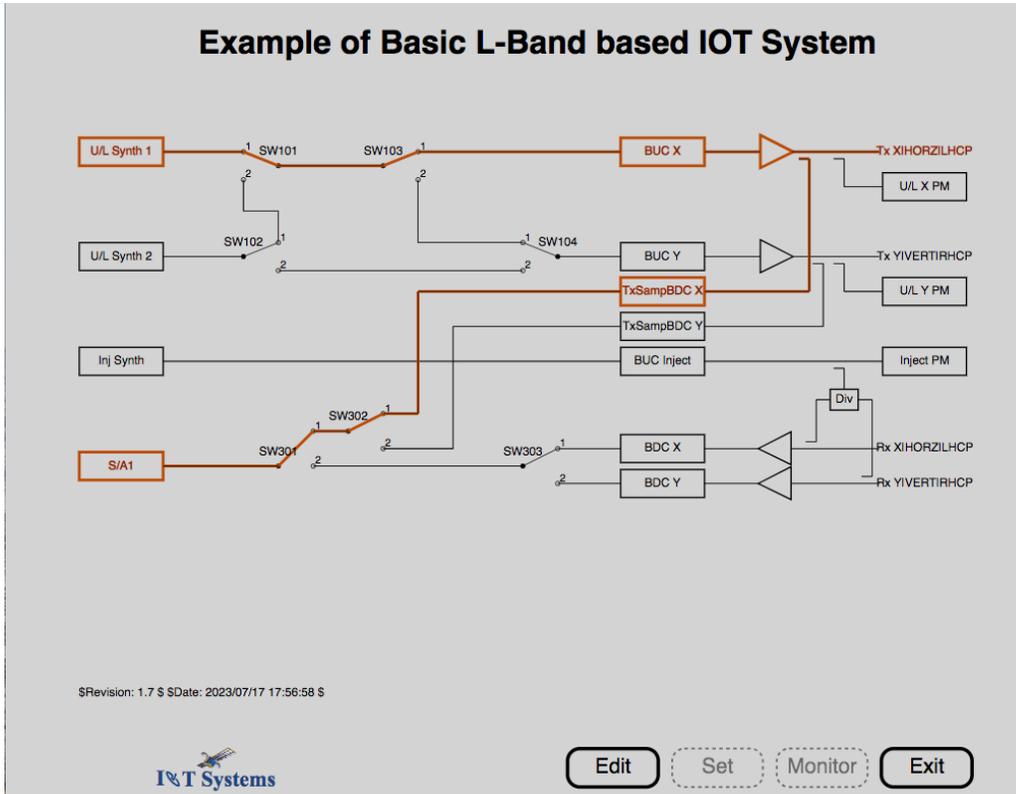

Figure 4-1 Example *of Basic L-Band Based Mimic Panel*

4.3 Workstation Interactions with the IOT

When the user edits the configuration and presses the [Set] pushbutton, the workstation issues a request for a configuration change to the switch control units. The workstation sends the switch requests to the Switch control unit(s) and the resulting state is shown on the mimic panel.

The Graphic mimic panel only checks the switch positions after a **[Set]** or **[Monitor]** is pressed, because of potential interactions with running measurements the communication with the Switch control unit(s) is limited to User interaction when **[Set]** and **[Monitor]** are pressed. One thing that the user may do, run a measurement to a certain point, pause it, change the switch settings using the mimic panel, then continue the measurement, thereby "faking out" the measurement with a different set of conditions for the measurement, this is often done for investigation of problems in space or on the ground.

4.4 Panel Pushbuttons

The GMP control panel contains four pushbuttons in the lower right corner which enable the user to control the panel's mode. They are:

- [Edit]
- [Set]
- [Monitor]
- [Exit]

[Edit]

When [Edit] is pressed, the GMP enters the edit mode and displays the configuration for editing. Hardware switches do not change position until the [Set] pushbutton is pressed.

[Set]

When [Set] is pressed, the GMP, via the switch control unit(s), commands the hardware switches their new positions.

[Monitor]

When [Monitor] is pressed, the GMP enters the monitor mode and displays the current configuration. The configuration cannot be changed from the GMP while it is in monitor mode.

[Exit]

When [Exit] is pressed, the GMP closes.
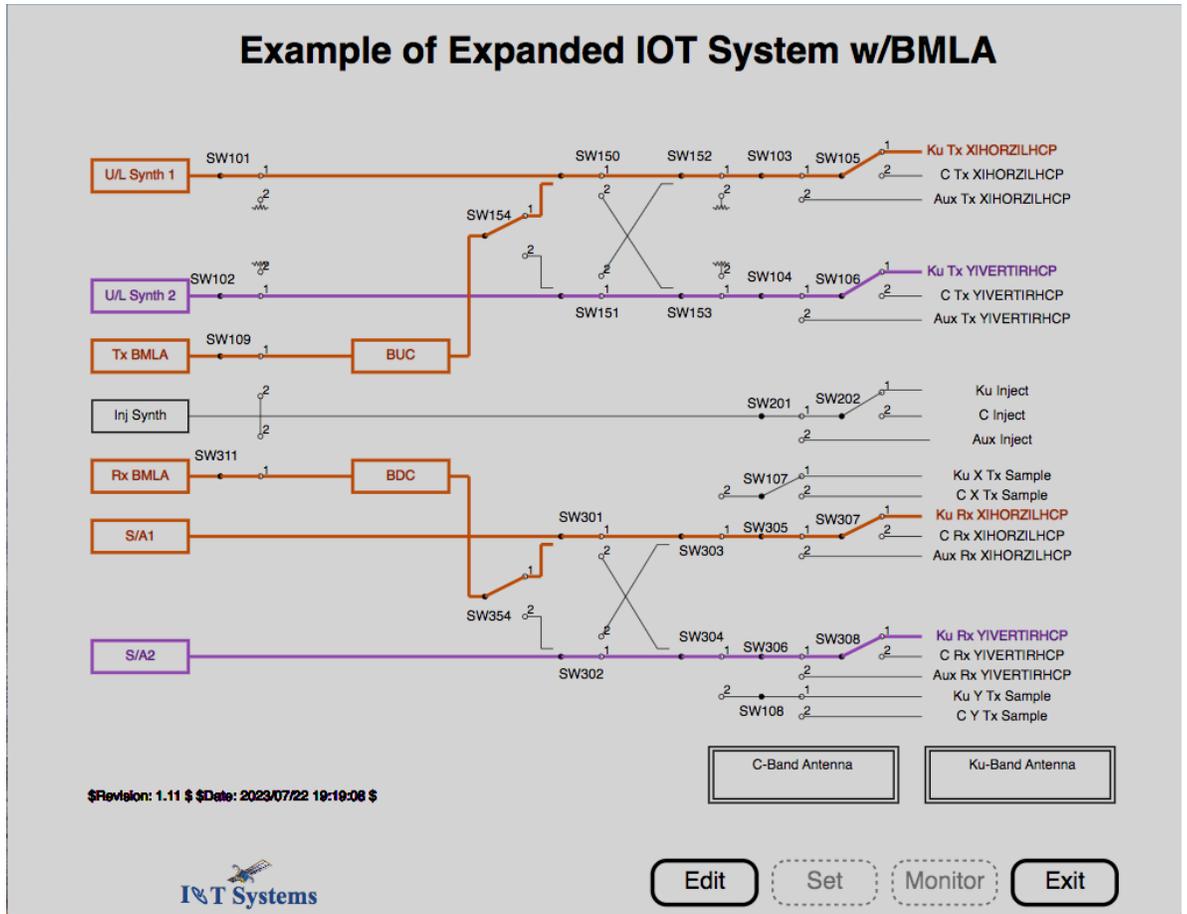
Figure 4-2 Example of Expanded System w/BMLA

4.5 Switch Control

The GMP permits the user to change the IOT configuration by changing switch positions, and this procedure is described next.

4.5.1 Mimic Panel vs. Automated Control

There are two modes of IOT switch control:
> a) Mimic panel control
> b) Automatic measurement control.

When the mimic panel first opens it queries all of the switches and displays the current state. To obtain the current state at any time the user can select **[Edit]** and then **[Monitor]** and the current state will be shown.

When it is in monitor mode, the GMP displays the current configuration, regardless of what mode caused switch position changes (i.e., from the workstation or manually).

4.5.2   Switch Change Procedure

The basic procedure for changing IOT switch positions is as follows: 1) press the **[Edit]** pushbutton to enter edit mode, 2) select a switch using the mouse and click on it to change its proposed position, 3) continue setting additional switches as desired, 4) when satisfied with the new configuration, press the **[Set]** pushbutton to execute the new configuration. When **[Set]** is pressed, the workstation commands the Switch control unit(s) to change the switch positions in the switch hardware, queries all of the switches, and then displays the new IOT configuration.

If the **[Monitor]** pushbutton is pressed instead of the **[Set]** pushbutton, the GMP queries all of the switches and displays the current state without changing the actual IOT switch configuration.

If the **[Exit]** pushbutton is pressed instead of the **[Set]** or **[Monitor]** pushbuttons, the GMP window is closed without changing the actual IOT switch configuration.

Let's try an example, open Example of Basic L-Band based IOT System and you will note it is showing the same configuration as displayed in Figure 4-1. You should also note that all switches are currently in position 1. Press **[Edit]** and click on SW103, SW301, and SW303 to change them to position 2 and Press **[Set]**. You will see the highlighted path change, the GMP highlights active paths to make it easy to see what paths are active. Everything is easily modified, the paths, the switches, the highlight colors, the number of panels. What is shown here is merely a potential design. The system can change dramatically and still require no new software.

4.6 Ku-Band Antenna Sub-panel

The Ku-Band Antenna Sub-panel is invoked by clicking the mouse on the "Ku-Band Antenna" box of the IOT Graphics Mimic Panel. The proposed sub-panel is depicted on Figure 4-3.

The Ku-Band Antenna Sub-panel displays the paths in the Ku-Band Antenna hub.

4.7 C-Band Antenna Sub-panel

The C-Band Antenna Sub-panel is invoked by clicking the mouse on the "C-Band Antenna" box of the IOT Graphics Mimic Panel. The proposed sub-panel is depicted on Figure 4-4.

The C-Band Antenna Sub-panel displays the paths in the C-Band Antenna hub.
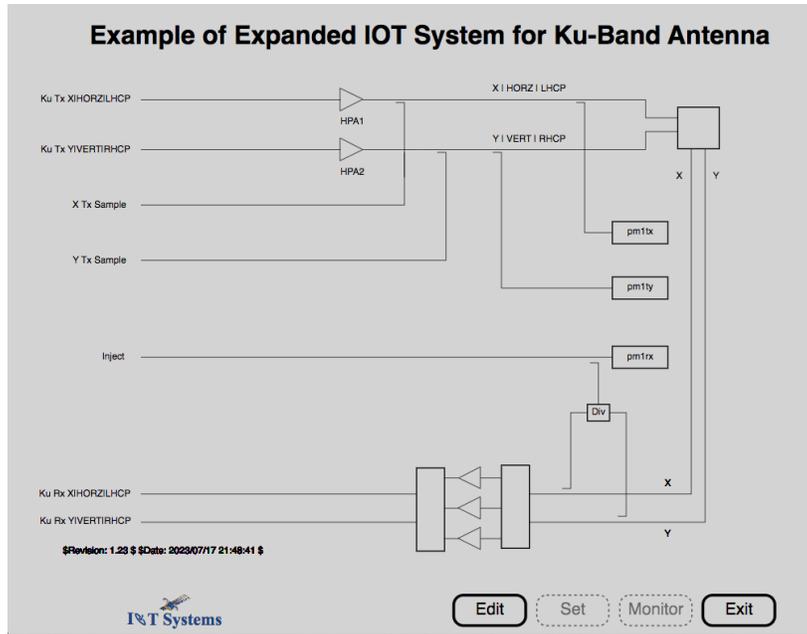
Figure 4-3 *Ku-Band Antenna Sub-panel*
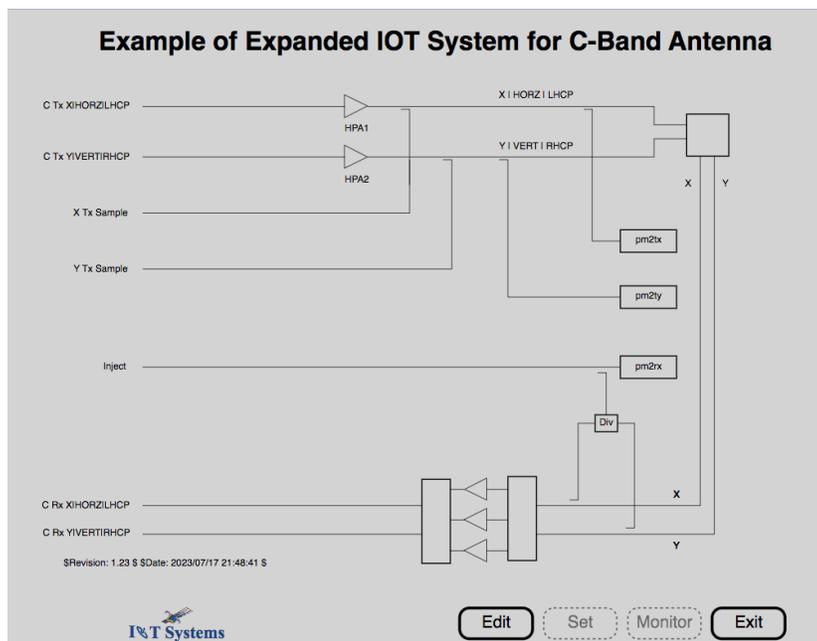
Figure 4-4 C-Band *Antenna Sub-panel*

4.8 IOT Equipment Control

All IOT equipment functionality is available via keyboard commands as well as access to simple control and status of instrumentation in the system via the "Instrument Status" window shown in figure 5-1 on page 5-2 and a static sample is available on our Instrument Status Demo page.

Instrument Status

5.1   Management Summary

- At a glance and in real time the operator can see the current state of the IOT Test Equipment via the browser-based Instrument Status & Control panel.

- With the user having control the switching from the Mimic Panel and control and status of the test equipment, a user can quickly perform manual measurements which is often very valuable.

- Many operations with the test equipment are possible with web enabled devices, multiple instruments and multiple web pages makes that activity slow and cumbersome. It's often been frustrating to watch, and with the browser-based Instrument Status & Control panel it's quick and easy.

- When the user is satisfied and instructs the Graphic Mimic Panel to "Set" the new configuration, the software automatically executes, confirms, and displays the new configuration.

5.2   Introduction

The Graphic Mimic Panel (GMP) is the primary switch control panel for the IOT user. The Switch control unit(s)are accessed from the GMP.

The user can change the state of any of the user-accessible RF switches by using the IOT Graphic Mimic Panel or manually at the equipment racks and antenna Hub. Although the GMP permits the user to change switch positions, generally, the IOT implements passive switch control. That is, the IOT does not throw hardware switches unless specifically requested by the user, permitting maximum user flexibility. The exception to passive control is when the IOT is performing IOT measurements. In this case the IOT commands the Switch Control Unit to throw the appropriate switches to automatically configure and perform the measurements.

5.3 Instrument Status & Control Main Window

The Instrument Status & Control Browser window is a very powerful tool for checking on the instrumentation and performing manual measurements, zeroing power meters, setting levels and seeing instrument responses to various stimuli. Because of the potential of many measurements, to make things easier the instruments are separate pages based on instrument type. To see that type click the Show/Hide button.
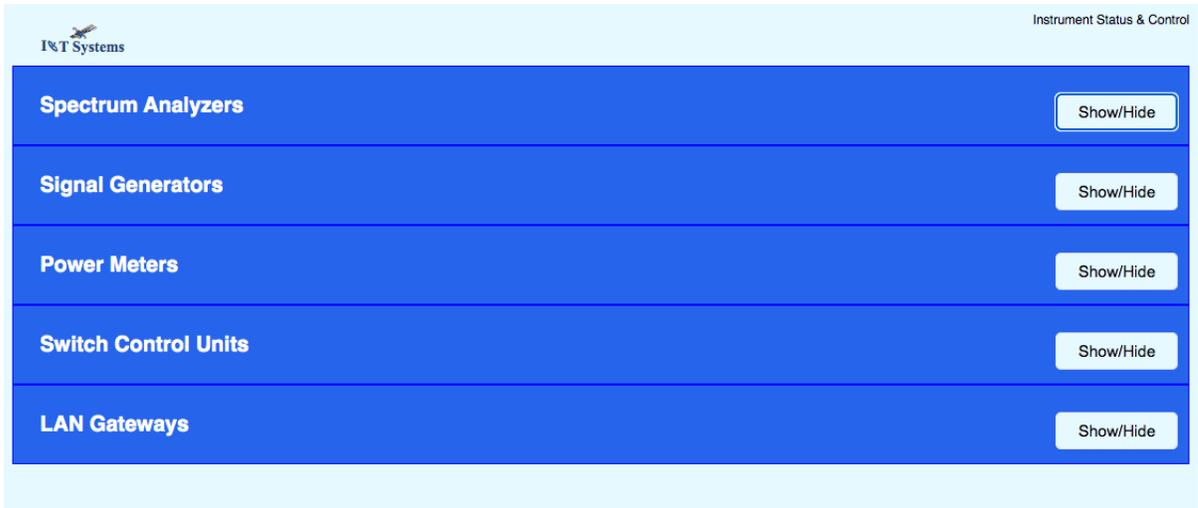
Figure 5-1 *Instrument Status & Control browser window*

5.4 Spectrum Analyzers

On the left of the window is information about the instrument, the logical name in the system, the driver that is used by the IOT software for this instrument, the manufacturer, the model number, serial number, options, capability, if it can automatically sink to a time-based reference, and if it is on internal or external reference. If an external reference is connected, if the user clicks on the Red external button, it will toggle to external and will turn green.

In the middle is an error message if there is an error, to clear errors, just click the red error button until it turns green and say no error.

On the right side is the type of instrument, the device name in the system, and GPIB address, if the GPIB address is -1 it means it is not using a GPIB address and is probably controlled via its LAN interface. Control sa1 pops up a window to change some of the settings on the Spectrum Analyzer, the Plot sa1 pops up a window and plots the data that is on the display, it supports both time domain and frequency domain plots. If the instrument has a web page there will be a button to provide easy access.

Figure 5-2 *Spectrum Analyzers*

5.5 Control sa1

Typical settings for the Spectrum Analyzer are available to set the frequency, power and levels.

Figure 5-3 *Control sa1*

5.6 Plot sa1 in frequency domain

Once you have opened the plot of the Spectrum Analyzer, you can also save the plot by pressing Store.
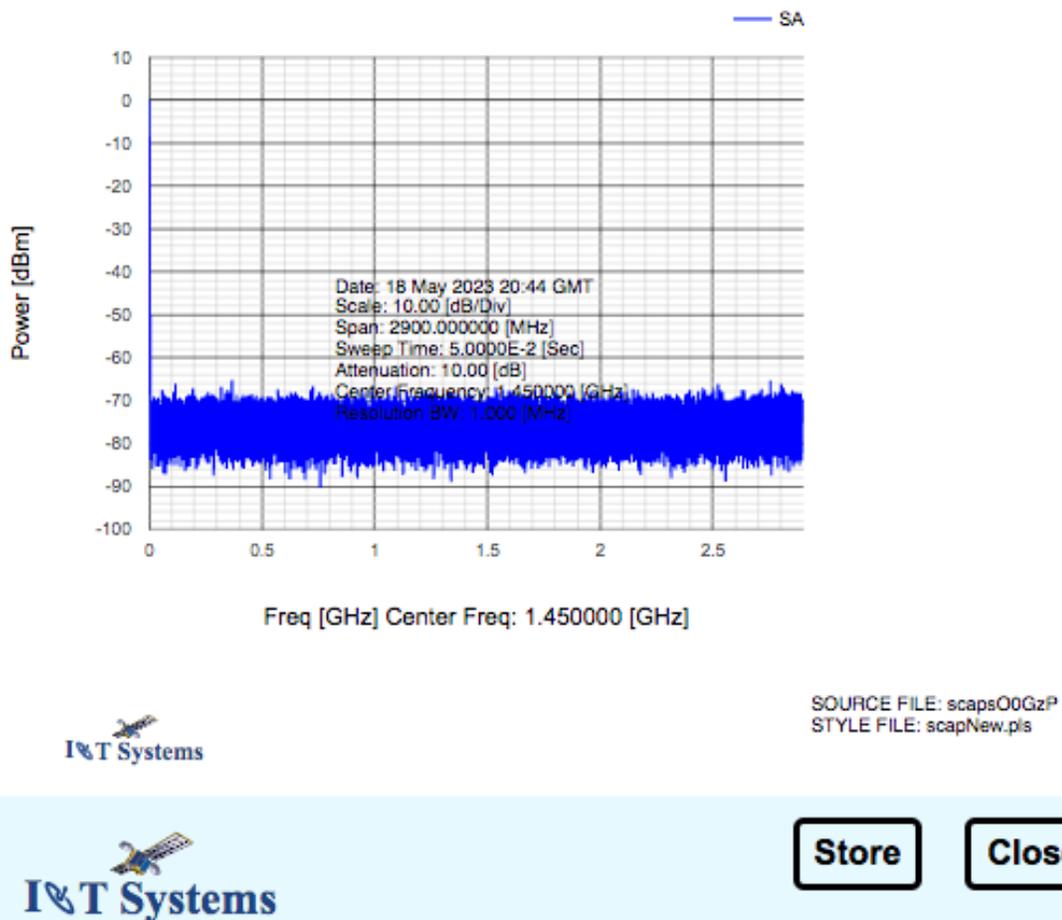
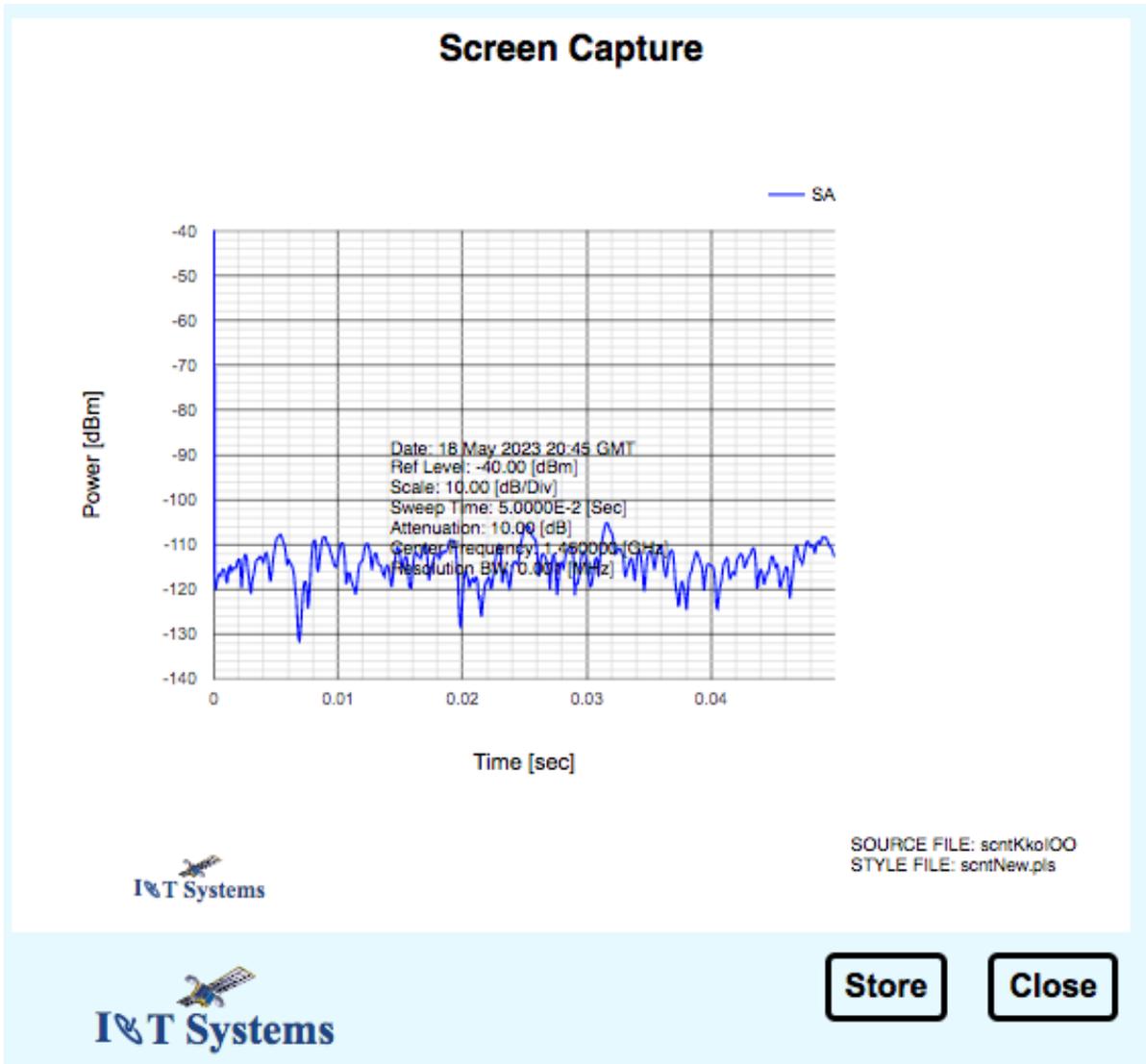

Figure 5-4 *Frequency Domain Plot of sa1*

5.7 Plot sa1 in time domain

Once you have opened the time domain plot of the Spectrum Analyzer, you can also save the plot by pressing Store.

Figure 5-5 *Time Domain Plot of sa1*

5.8 Signal Generators

On the left of the window is information about the instrument, the logical name in the system, the driver that is used by the IOT software for this instrument, the manufacturer, the model number, serial number, options, capability, if it can automatically sink to a time-based reference, and if it is on internal or external reference. If an external reference is connected, if the user clicks on the Red external button, it will toggle to external and will turn green.

In the middle is an error message if there is an error, to clear errors, just click the red error button until it turns green and say no error.

On the right side is the type of instrument, the device name in the system, and GPIB address, if the GPIB address is -1 it means it is not using a GPIB address and is probably controlled via its LAN interface. The frequency & power are the setting when the window was loaded, if you want to set the frequency & power, type in **Freq**: & **Power**: fields and Press Set, to turn on/off the **RF** or **Modulation** simply toggle those buttons, green On, grey Off. If there is a **Web Page** button it means that instrument is also web enabled and you can open its web page as a pop-up through **Web Page**.

Figure 5-6 *Signal Generators*

5.9 Power Meters

On the left of the window is information about the instrument, the logical name in the system, the driver that is used by the IOT software for this instrument, the manufacturer, the model number, serial number.

In the middle is an error message if there is an error, to clear errors, just click the red error button until it turns green and say no error.

On the right side is the type of instrument, the device name in the system, and GPIB address, if the GPIB address is -1 it means it is not using a GPIB address and is probably controlled via its LAN interface. The frequency & PM Reading shown is what is retrieved when the window was loaded, if you want to set the frequency re-measure, type in **Freq**: value and Press **Measure**. If there is a **Web Page** button it means that instrument is also web enabled and you can open its web page as a pop-up through clicking **Web Page**. If you want to Zero the Power Meter press Zero <pm name> and a window will pop up indicating the zeroing operation has completed. Note that the date and time of the **Last Zero** is shown below the **Zero pm** button.

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Figure 5-7 *Power Meters*

5.10 PM Zero Pop-up

The PM Zero Pop-up is opened to indicate the completion status.
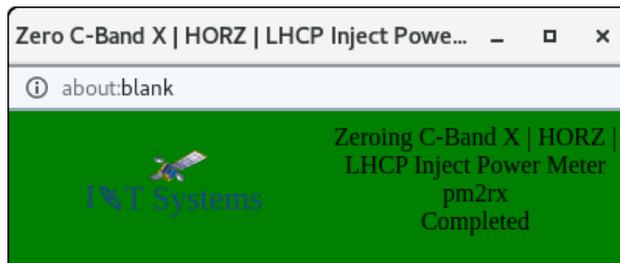
Figure 5-8 *Zero Power Meter Pop-up*

5.11 Web Page Pop-up
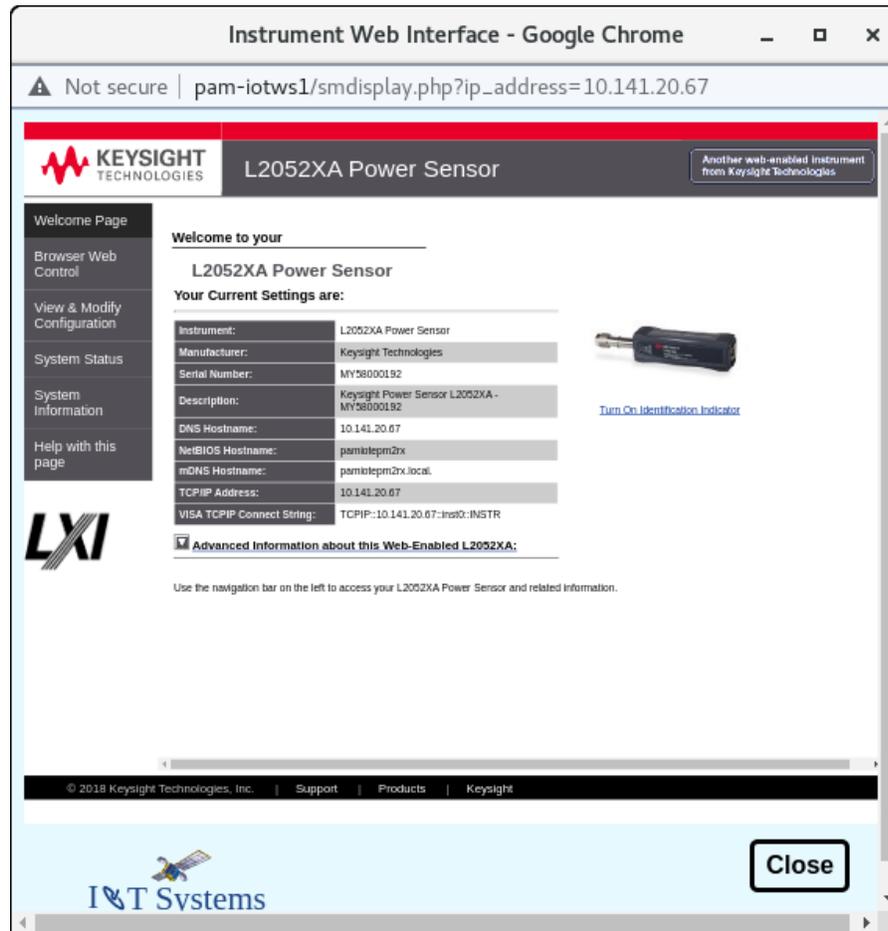
Figure 5-9 *Power Meter Web Page*

5.12 Switch Control Units

On the left of the window is information about the instrument, the logical name in the system, the driver that is used by the IOT software for this instrument, the manufacturer, the model number, serial number.

In the middle is an error message if there is an error, to clear errors, just click the red error button until it turns green and say no error.

On the right side is the type of instrument, the device name in the system, and GPIB address, if the GPIB address is -1 it means it is not using a GPIB address and is probably controlled via its LAN interface. If there is a **Web Page** button it means that instrument is also web enabled and you can open its web page as a pop-up through clicking **Web Page**.

Figure 5-10 *Switch Control Units*

5.13 LAN Gateways

On the left of the window is information about the instrument, the manufacturer, the model number, serial number.

On the right side is the type of device, the device name in the system, LAN Timeout, GPIB Name, GPIB address and GPIB Unit. If there is a **Web Page** button it means that instrument is also web enabled and you can open its web page as a pop-up through clicking **Web Page**

Figure 5-11 *LAN Gateways*

5.14 Example of Instrument Status window usage

In this example, we will set the Inject and measure on the power meter and the spectrum analyzer. First set the power and frequency of the Inject Signal Generator to 3.7 GHz and 0 dBm and press **Set** with **RF Off**. Then zero the inject Power meter. Set the frequency for the Power meter to 3.7 GHz.

Now set the Spectrum Analyzer to 3.7 GHz, 10 MHz Span, 100 KHz Res Bandwidth, 100 KHz Video Bandwidth. And Press **Update sa1**. Press **Measure** on the Inject Power Meter, we should be measuring noise on both the spectrum analyzer and the power meter. Press **Plot sa1** to see the display. Then click **RF Off** to toggle to **RF On** and green for the Inject signal generator and press **Measure** on the Inject Power Meter and **Plot sa1** for the spectrum analyzer . You should see a signal on the Power Meter and the Spectrum Analyzer. Since the Inject Signal Generator is set to 0 dBm the measurement on the Power Meter and Spectrum Analyzer should be the gain or loss to those instruments. If you want you may store the data for the plot in the system.

One thing to note is that if you move your cursor over any plot on the screen you will see the current x & y values displayed by the cursor.

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The use or disclosure of this information is subject to the restrictions on the title page.

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Appendix A

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The bibliography is classified into two categories: "Technical Paper References" and "Computer and Software References".

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Terms and Acronyms

1. AGC   Automatic Gain Control
2. ALC   Automatic Level Control
3. AM   Amplitude Modulation
4. ANSI   American National Standards Institute
5. ARO   After Receipt of Order
6. ASCII   American Standard Code for Information Interchange
7. IOT   Automated Test Subsystem
8. bps   bit per second
9. CDR   Critical Design Review
10. CFE   Customer-Furnished Equipment
11. C/N   Carrier-to-Noise Ratio
12. CPU   Central Processing Unit
13. CSM   Communications System Monitoring
14. CTDS   Component Tracking Database System
15. DAT   Digital Audio Tape
16. DAU   Data Acquisition Unit
17. D/C   Downconverter
18. DIO   Digital I/O card
19. D/L   Downlink
20. EIRP   Effective Isotropic Radiated Power
21. EMI   Electromagnetic Interference
22. E/S   Earth station
23. EUTELSAT   European Telecommunications Satellite Organization
24. FAT   Factory Acceptance Test

25. FCO	Frequency Conversion Offset	
26. FDDI	Fiber Distributed Data Interface	
27. FM	Frequency Modulation	
28. GB	Gigabyte	
29. GDV	Group Delay Variation	
30. GMP	Graphic Mimic Panel	
31. G/T	Gain-to-Temperature ratio	
32. GUI	Graphical User Interface	
33. HP	Hewlett-Packard Company	
34. HPA	High-power amplifier	
35. HPIB	Hewlett-Packard Interface Bus	
36. IEEE	Institute of Electrical and Electronics Engineers	
37. IF	Intermediate Frequency	
38. I/O	Input-Output	
39. IOT	In-orbit Test	
40. IPFD	Input Power Flux Density	
41. KPA	Ku-band Power Amplifier	
42. LHCP	Left Hand Circular Polarization	
43. LAN	Local Area Network	
44. LNA	Low-Noise Amplifier	
45. LO	Local Oscillator	
46. Mbps	Megabits per second	
47. MB	Megabyte	
48. MFLOPS	Millions of floating-point operations per second	
49. MIPS	Millions of instructions per second	
50. MPCP	Measurement Processing And Control Platform	
51. MUI	Measurement User Interface	
52. MUX	Multiplexer	
53. NASA	National Aeronautics And Space Administration	
54. N/A	Network Analyzer	

55.	OSF	Open Software Foundation
56.	PM	Phase Modulation
57.	PSDN	Public Switched Data Network
58.	PSTN	Public Switched Telephone Network
59.	QPSK	Quadriphase Shift Keyed (modulation)
60.	RCS	Revision Control System (UNIX)
61.	RF	Radio Frequency
62.	RFQ	Request For Quotation
63.	RFI	Radio Frequency Interference
64.	RFTS	RF Terminal Supervisor (for NASA ACTS)
65.	RHCP	Right Hand Circular Polarization
66.	RISC	Reduced Instruction Set Computing
67.	RSS	Root-Sum-Square
68.	SAT	Site Acceptance Test
69.	S/A	Spectrum Analyzer
70.	S/C	Spacecraft
71.	SCSI	Small Computer System Interface
72.	SFD	Saturation Flux Density
73.	TEIRP	Telemetry EIRP (see "EIRP" above)
74.	TLT	Test Loop Translator
75.	TWTA	Travelling Wave Tube Amplifier
76.	U/C	Upconverter
77.	U/L	Uplink
78.	WAN	Wide Area Network
79.	W/S	Workstation

Appendix C

Reprint of AIAA Paper

"In-Orbit Test And Monitoring Systems Architecture" Paper presented

at

The American Institute of Aeronautics and Astronautics'
The 14th International Communication
Satellite Systems Conference And Exhibit
(Washington, D.C., March 22-26, 1992)

Appendix D

·Reprint of CTR Spring 1993

- *"CTR Spring 1993, In-orbit Testing, V.23-1" several articles*