WV Communications

FTS Products System Overview

DESCRIPTION

WV Communications, Inc. is the world's leading supplier of ground-based flight termination equipment. WV has a broad line of FTS products that make up a turn-key flight termination system, from the control subsystems to the power amplifiers. The flight termination systems provided by WV range from transportable systems with local front-panel control to high power systems with multiple control sites. WV provide systems that meet every customer's requirements. Since WV controls all aspects of the design, from hardware to firmware development, and manufactures all system components in house, we can meet any specific customer requirement, be it a custom hardware requirement or a particular control feature.

WV's latest generation of FTS is based entirely on Ethernet communications between devices. As part of the control subsystem, WV has designed and manufactured a number of Flight Termination Panels (FTP), FTS Control Processors (FCP), and FTS Status & Control Panels (FSC), with each unit operating using a firmware written entirely in assembly language. No real-time operating system of any kind is used. Each of these units have been designed based on specific requirements, however the versatility of the firmware is such that the units can be configured for numerous operating scenarios.

Based on inputs from numerous FTS operators, WV has developed the application software for its FTS Programming System (FPS). The FPS software, which can be loaded in any personal computer, operates on a Linux platform, and allows the system operator to configure the FTS to support the mission requirements. The FPS provides all of the system programming and data logging functions, however it is not a flight critical piece of equipment. The FPS is not required while a mission is in progress.

As part of the transmitter subsystem, WV has a full complement of Command Exciter/Encoders (CEE) and Command Verification Receiver/Decoders (CVR), with units capable supporting IRIG, Hi Alpha (Secure) and EFTS modes. Units are available that will support a single mode or any combination of all three modes.

Lastly, WV has a variety of power amplifiers to meet any customer requirement. From 20 Watts Solid State amplifiers embedded in the CEE chassis to stand-alone rack mounted amplifiers ranging in power from 200 to 10,000 Watts.

WV's system architecture allows for up to sixteen (16) FTPs, sixteen (16) FCPs, twenty (20) FPS' or FSCs, and sixteen (16) transmitter strings. A block diagram of an FTS having three (3) transmitter sites is illustrated in Figure 1.

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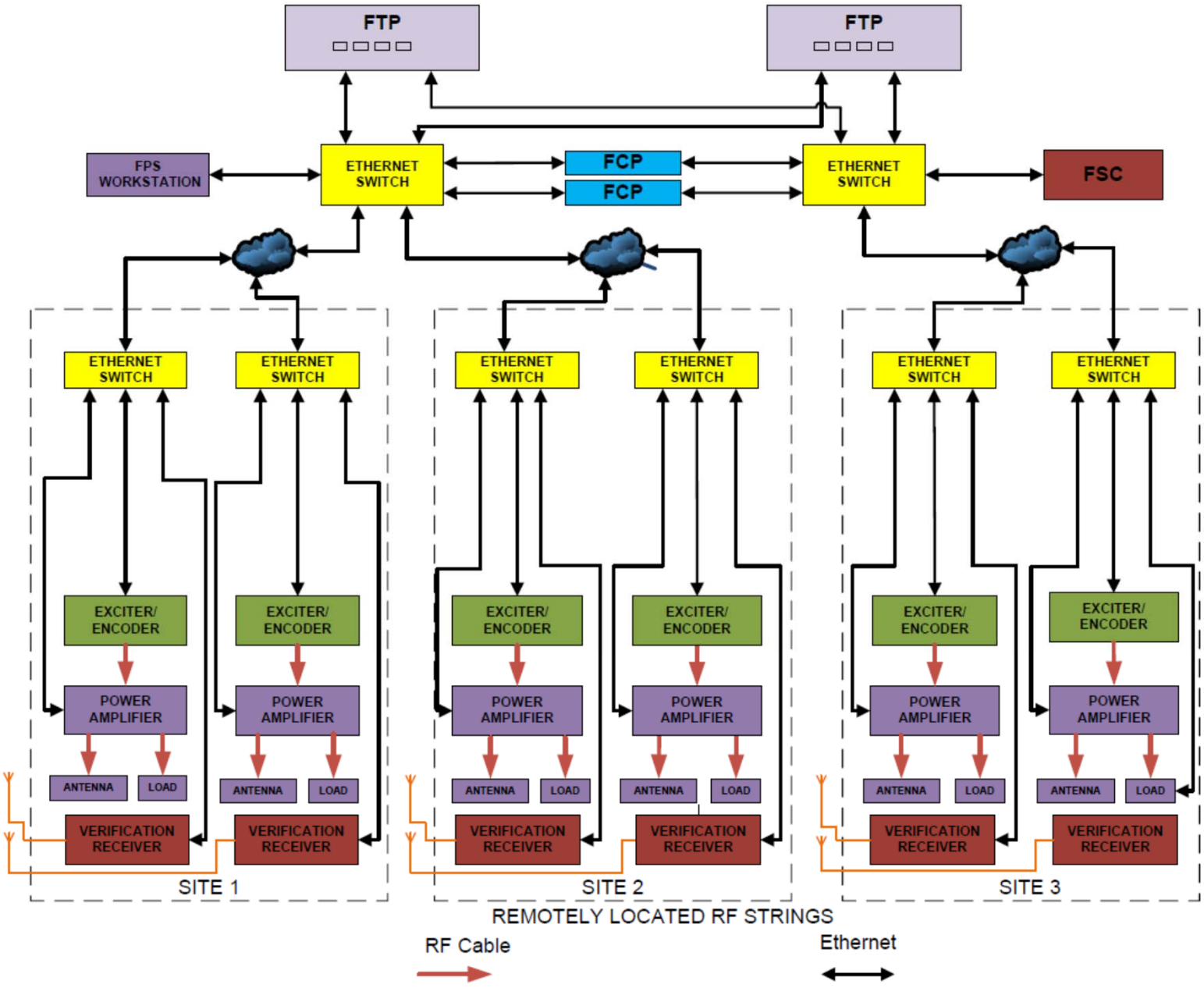

Figure 1 – 3 Transmitter Site FTS Block Diagram

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FTS Definitions

The following terms are helpful definitions in understanding the system and its capabilities. Some represent physical pieces of equipment that make up the system. Others represent logical concepts.

FTS Control Processor (FCP). The FCP is the heart of the system. It is a “black box” that the other components of the system communicate with. It contains non-volatile memory (NV) that stores configuration information for the system and for missions run by the system. It does the necessary translation and sequencing / prioritization between user input and the system RF equipment.

Flight Termination Panel (FTP). The FTP is the operational command entry device. It’s functionality is often referred to as an RSO, RDO, etc. panel. This is where the Range Safety Officer presses buttons that results in flight termination commands being transmitted. Various configurations of the FTP are available.

FTS Programming System (FPS). The FPS is a computer workstation that serves as a configuration user interface for the FCP. This functionality was separated from the FCP in order to make it easy for the FCP to be designed as a mission safety critical piece of equipment. The FPS is needed to configure the system, as well as the mission, and to start and stop missions, but it is not necessary for it to be functional for a mission to operate, once the mission is started. While a mission is running the FPS does provide the benefit of logging the mission data to the computer’s hard drive.

FTS Status and Control panel (FSC). This is a device that implements a subset of the FPS functionality with a more operationally oriented user interface. Because the FPS provides a rich graphical user interface, it runs on a commercial operating system and is not designed to safety critical standards. The FSC, with its more limited user interface is designed to safety critical standards. It cannot change configuration, or start or stop a mission, but it can show the status of devices in the mission and change the carrier state, antenna type or active transmitter string.

Transmitter String. A transmitter string consists of a Command Encoder Exciter (CEE), which generates a modulated carrier at low power level containing commands requested through the system, a High Power Amplifier (HPA) that amplifies this low level signal to a suitable level to be transmitted via an antenna, and a Command Verification Receiver/Decoder (CVR) that monitors this signal to insure that it meets the requirements of the protocol and mission, and is indeed what is being requested.

Set. One or more FCPs. Within a set, one FCP is active and the others are backups. If the active FCP fails, the first designated backup automatically replaces it. A set typically consists of at least two FCPs for redundancy.

Mission. The collection of configuration data. The mission describes the equipment designated to be used in sending commands to one or more vehicles and the commands to be sent. While a mission is running, it must have access to at least one FCP, one FTP, and one Transmitter String. In general, a mission will include at least two FCPs and two Transmitter Strings for redundancy.

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Vehicle. The vehicle under control of a mission—a launch vehicle, UAV, drone, etc. The concept of a vehicle facilitates organizing commands, defining Arm/Terminate cycles, and in EFTS, associating Range IDs and Vehicle IDs with commands.

Group. A group is one or more Transmitter Strings that are considered operationally equivalent. If the primary transmitter fails, the system can be configured to automatically replace it with one of the others in the group. There is no specific number of transmitters that must be in a group, although a minimum of two is recommended. The system will never automatically transfer control outside the group, because other transmitters may not be suitable at the time of transfer (down range and not yet in range, for example). However, an operator, knowing that a transmitter in a different group is acceptable (or even preferable) can manually transfer control to it.

An FTS generally consists of two or more FCPs and associated equipment. The FCPs may be divided into a maximum of four sets. There are several ways of assigning vehicles to missions and missions to sets. More than one vehicle may be assigned to a single mission, or vehicles may be separated into multiple missions. Missions that use the same frequency and protocol (except High Alphabet) can share transmitter strings, just as vehicles in the same mission can. The primary difference is that an FTP can only be assigned to a single mission, so any vehicles that have buttons on the same FTP must be in the same mission. Conversely, while multiple FTPs can be assigned to a mission, with different commands on each, one way to force different FTPs for each vehicle would be to make a separate mission for each vehicle.

The FCPs in a set can run several missions simultaneously. These can share the same transmitter or can use different transmitters. Missions using FCPs in the same set are likely to be related (main vehicle and drones, for example). Likewise missions sharing the same transmitter are even more likely to be related, although neither of these is required.

Missions on different sets of FCPs are more isolated from each other. The concept of a set was developed, not for technical reasons, but to avoid the perceived risk of resource sharing between unrelated missions. Different sets of FCPs provide separate execution for different missions. While they share the same pair of LANs, they do not share equipment or processing, providing isolation. There is limited communication between the FCPs in different sets in order to manage the pool of equipment and prevent unrelated missions from attempting to use the same equipment.

There is no technical reason that mandates use of multiple sets for multiple missions. Any two missions that can be run on two sets of FCPs can be run on the same set. Running them on different sets just offers assurance that one customer’s mission will not interact with another’s.

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FCPs could be used in totally separate systems, however that would make resource sharing more difficult. If a transmitter string, or an FTP, was used by a different system, it would have to be physically disconnected from one system and then connected to the other system. It's IP address(es) might need to be changed, and both systems would have to be reconfigured to recognize the loss of the resource from one system and its addition to another system. By putting all the equipment into a single system, but dividing it into sets, a pair of LANs is shared by all the equipment and each piece of equipment can be allocated to one set, or another, as needed, while still preserving the isolation afforded by separate FCPs doing their own processing, and by devices being locked to the set for the duration of the mission, and thus not accessible to other sets. Also, since the same configuration data is stored in each FCPs NV memory, a mission can be run from either set with little or no change.

The FCPs are the only devices that are permanently assigned to sets. They can be moved to different sets administratively if neither the old or new set is running a mission, but this is likely to be infrequent.

FTPs belong to a set only when a mission is started that use them. Once assigned to a mission, they cannot be accessed by any other mission (same set or different set). WV makes two types of FTPs; one that uses Ethernet communications and one that uses voice grade modems. The type that uses voice grade modem communication has physical links to the FCPs in a set, so can only be used by missions running on that set.

The FPS belongs to a set when it attached to an FCP in that set. Any mission it starts will be started on the FCPs in that set. It also can attach itself to a mission to give status information on that mission or control it if allowed. It can detach from the mission and attach to a different running mission without stopping or otherwise impacting the missions. It can also attach to an FCP in a different set and to any running mission on that FCP. It can be attached to only one set and one mission at a time, but has the flexibility to switch, as needed. Most installations relegate the FPS to being a status monitoring device while a mission is running (i.e. a read-only device that is not allowed to change anything related to the mission). Any active control is handled by the FSC. For that reason it is reasonable for a single FPS to be moved between missions if the criticality is low. The FPS collects logging information and stores it on disk, so for logging purposes there should be at least one FPS connected to each set of FCPs during a mission. Because the FCPs have buffers, even this requirement can be relaxed on missions with little activity.

The FSC also belongs to a mission or set only when the operator chooses to attach it to a mission. Normally an FSC would be attached to each mission shortly after it is started, but that isn't required if quick access to make changes is not needed. In particular, missions that share the same transmitter strings would not require separate FSCs, since the changes it makes are all related to the transmitter and thus would apply to all missions sharing the transmitter. However, missions running on different transmitter strings, including missions running on different sets of FCPs should have their own FSC.

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Transmitter strings are organized in groups. One or more groups of transmitters are assigned to a mission. Groups of transmitters may be assigned to multiple missions provided that; 1) all missions are assigned the same groups, 2) all missions use the same protocol, 3) the protocol supports multiple vehicles (High Alphabet does not), 4) all missions use the same parameters (frequency, power, etc), 5) both missions are running on the same set of FCPs (which means same active FCP). The FCP checks when a mission is started to insure that either it is using its own groups (not shared) or that it meets the above requirements and will not start the mission if it does not.

Protocols. WV's FTS support all three of the commonly used protocols (IRIG, High Alphabet (AKA Secure Tone) & EFTS) and offer sufficient flexibility to support numerous variations. Each protocol can send individual commands singly or repeatedly or steps made up of tones or commands.

IRIG is the oldest and most widely used protocol. Commands are made up of one or more tones from a set of 20. No precise timing requirements are imposed. Extended IRIG refers to commands made up of multiple steps, each of which has zero or more tones and a precise length. The Trident Missile X and Y commands can be implemented in this manner. FSK data commands have also been implemented this way. A requirement of IRIG is that Arm and Terminate share a "common" tone. This command must continue through any gap between Arm and Terminate. It must not be interrupted when switching between them. Even the phase of the tone should not have any discontinuities. The WV system handles common tones without a glitch, and can handle Arm/Term cycles for multiple vehicles and multiple missions (same or different transmitters) including multiple common tones.

High Alphabet (HA) uses a prescribed sequence of 11 pairs of tones to make commands. HA steps would involve a sequence of such commands. Because HA the command set is limited to five commands, the only sequence likely to be useful is a single button Arm/Terminate cycle. Since all three protocols can implement Arm/Term cycles in other ways, this has limited applicability. HA was never intended to support multiple vehicles. Receipt of a command made of tone pairs that doesn't match one of the 5 defined commands is treated as an error condition. HA was developed initially for manned space flight, and is the legacy system for secure commands. There are NSA approved methods for handling commands to mitigate the risk of clandestine termination of a vehicle. WV supports the use of a device called a High Alphabet Secure Message Unit (HAMSU) that fits in the FCP and stores sets of HA command definitions which are pushed to the CEE and CVR as needed, and zeroized immediately after use. We also support directly loading the command definitions into the CEE and CVR before mission start using a KYK-13 or similar fill device.

Enhanced Flight Termination System (EFTS) is the most recently adopted protocol, and is intended to replace both IRIG and HA. It is a digital protocol that is encrypted and has several identifier fields to prevent accidental interception of commands for a different vehicle as well as to avoid any clandestine attacks, including spoofing. EFTS frames are 10ms long and contain three "command" fields. The first is a one bit check field that is received without regard to vehicle ID. The second is the FTS command, which comes from a pre-defined set. The third is a 6 bit user defined field that can be used in any way imagined by the user. A single frame contains all three. Sequences of EFTS commands could contain two or more FTS commands (Arm and Terminate are the most likely) or two or more user commands.

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Arm/Term Cycle is a desirable feature that the system supports. If the commands are configured correctly, the Arm command will occur first when both are turned on, followed by the Terminate command. Each command will then alternate at the programmed rate. Because the Flight Receiver (FTR) will not act on a Terminate command if it hasn't just seen an Arm command, it is important for the FTR to see both. Since a vehicle is usually terminated because it is off course, there is a high probability that it may be in some sort of turbulent motion that places the receive antenna out of view of the transmitter at times. By alternating Arm and Terminate, maximum probability of the FTR seeing the two commands in succession in a reasonable period of time is insured.

ENABLES: FTPs, FSCs and FPS' have enables and permissions. The FCPs have a two position locking key switch that determines whether the system is in Setup (Enabled) or Flight (Disabled) mode. All FCPs must be switched the same for a change to occur. If one or more is different, the previous state is maintained until all are switched to the state not in use. Each FTP, FSC and FPS can be configured to be active in either or both of these modes. Active implies the ability to change or control the system. If a device is not active, then it serves only as an output indicator (a read-only device). When the device is active, additional configuration items determine what it can do. For instance, an FPS might be allowed to switch transmitters, but not send commands by VFTP. In addition, some devices are equipped with an Enable key switch that can be used to lock that device into a read only state.

Safety: While there are a few general hazards that are unrelated to flight termination, such as excessive noise level near equipment or standing in front of a high gain antenna connected to a high power amplifier, all safety issues related to flight termination trace back to two fundamental ones:

- A flight termination system shall not fail to deliver a properly qualified terminate command to an FTR when commanded to do so by the Range Safety Officer (RSO).
- A flight termination system shall not deliver a terminate command to an FTR unless told to.

All other safety requirements amount to details implied by one or both of these two. The primary way that WV implements the first requirement is through redundancy. All hardware in the critical path is duplicated. The FTP utilizes Front Panel Switches both normally open and normally closed type contacts connected to two different CPUs that communicate separately with the FCP. There are two or more FCPs and two or more transmitter strings. In addition, all equipment monitors itself to insure proper operation, and the CVR provides confirmation feedback, both to the correct transmission of the intended command and that the parameters defining that command are within tolerance.

The second requirement is met by redundant data paths and computation. This exists throughout the command delivery path. The FTP switch normally open and normally closed contacts provide complementary views of the state of each switch. This complementary view is maintained through the entire system, and must remain complementary, or no action is taken and a fault is reported. Additional data integrity check and confirmation steps at key points insure accurate data before anything is transmitted.

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Equipment Configuration: The following quantities apply to various parts of the system:

- FCPs – The system can have a maximum of 16 FCPs. The practical minimum is 2 (one set)
- Sets – The FCPs can be organized into a maximum of 4 sets. A minimum of 1 is required.
- FTPs – A system with Ethernet based FTPs can have a maximum of 16 FTPs, which can be shared on a per mission basis among sets. A system with voice modem based FTPs can have a maximum of 36 FTPs, of which a maximum of 9 can be in any one set. The minimum for the Ethernet system is 1 FTP (for one set and one mission running at any one time). The voice modem based version must have 1 FTP for each set because the FTPs are hardwired to the FCPs.
- FSCs and FPS' are treated the same by the system. There can be a total of 20 between them, with no more than 10 being FPS'. The minimum is one FPS and no FSCs, although recommended minimum is 1 FPS and one FSC for each set or transmitter string in simultaneous use (if more than one mission using separate transmitters is run on a set). In practice most users will have at least one of each per set.
- Transmitter String – Maximum 16, theoretical minimum 1, practical minimum 2. If multiple simultaneous missions using separate transmitters, or multiple sets are planned, then 2 times the number of simultaneous missions or sets.
- Groups – A maximum of 8 groups is allowed. Minimum 1
- Missions – The standard system can store 32 missions in NV memory. Unlimited missions may be moved back and forth between the FPS hard drive and NV memory. Missions may be shared between sets.
- Commands – The standard system can have 32 commands per mission. These may be distributed across any combination of FTPs either identically, or in an overlapping manner, or a non-overlapping manner.

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