A Federal Standard for HF Radio Automatic Link Establishment

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Abstract

Development of high-frequency (HF) automated radio standards was initiated by the Federal Telecommunications Standards Committee's HF Radio Subcommittee, which is chaired by an Institute for Telecommunication Sciences (ITS) staff member. The ITS contributed strongly to Federal Standard 1045 (FS 1045), the first in a family of HF automated radio standards. This standard, which addresses HF Automatic Link Establishment (ALE) functions, will provide the foundation for developing an entire family of HF radio standards. FS 1045 provides the technical guidance for the protocol of the call, response, and acknowledgment signals. The emission waveform contains address information that will selectively alert a station and will invoke a response from that station if the station is not mute. The standard specifies the required protocols and timing but leaves implementation to the creativity of the radio designer. This paper describes the process, developed by ITS, that was successfully used to develop FS 1045.

Background

The process used to develop FS 1045 is unique for development of Federal standards. Most Federal standards are based upon a piece of existing equipment that is already in use by Federal agencies. The process developed for FS 1045 includes documenting the user requirements, and then using those requirements to specify hardware for fulfillment of the requirements. A comprehensive set of tests is then used to validate the hardware and to show proof that the hardware does meet the specification. After these steps are completed, the standard can be written.

The ITS's current work is focused on developing a family of standards for addressing automated HF radio systems. When fully implemented, these standards will substantially improve radio communications interoperability within and among civilian Federal agencies, emergency preparedness organizations, and the US military departments. They will also enhance competition and promote new product development in the US telecommunications industry.

A "new" interest in the use of high-frequency (HF) radios has emerged. The attributes of versatility and reliability of the HF radio have been proven by day-to-day and emergency use during the past 50 years. These attributes point out the distinct advantage of HF radios over "fixed" media such as terrestrial cable, satellite, and microwave/millimeter-wave communication links.

The advent of automated HF radio has caused a concern that implementation should happen in a way that will benefit the most users. In addition, the advent of automated HF radio provides an opportunity to improve the reliability, the durability, the survivability, and the interoperability of the Nation's telecommunication system.

Provision for standardization of the equipment and the concepts used for automation of the HF radio functions was thought to be the most beneficial way to exploit this opportunity. Several studies were launched in an effort to search out the best ideas for automating the radios—ideas and concepts that would yield the most interoperable and compatible HF radio equipment package.

Compatibility with international standards such as the Integrated Services Digital Network (ISDN) and consideration for the needs of military and civilian Government agencies were used to design the waveform that has become the backbone for the implementation of a series of HF standards.

The first standard, referred to as the HF Radio Automated Link Establishment (ALE) Federal Standard 1045 (FS 1045), has been completed and is in the review process by industry, the public, and the Government before publication. This standard will be followed by a series of enhancement standards that will complement and add to FS 1045.

The functions necessary to automate the HF radio system were defined at the beginning of the project. Figure 1 is a pictorial description of these functions in a stair-step format. The functions on the lower stair-steps should be implemented first. Only the first four steps are implemented in Federal Standard 1045 as shown.

The remaining functions will be implemented in future standards. A family of proposed Federal Standards (pFS)

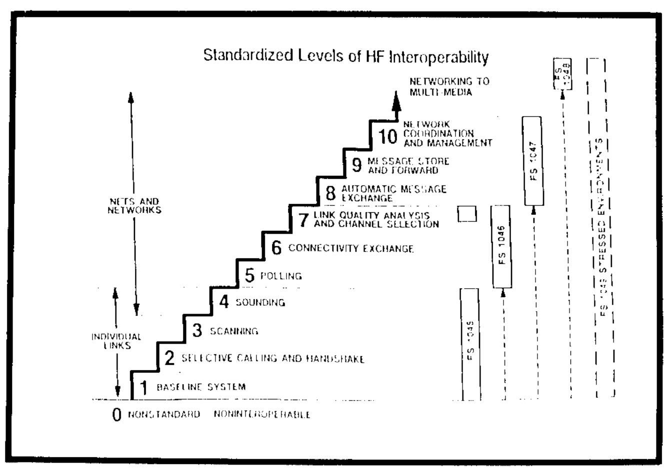

Fig 1—Functional levels of automated HF radio systems.

is planned as follows:

pFS 1045 - HF Radio Automatic Link Establishment
pFS 1046 - HF Radio Automatic Networking
pFS 1047 - HF Radio Automatic Message Store and Forward
pFS 1048 - HF Radio Automatic Networking to Multimedia
pFS 1049 - HF Radio Automatic Operation in Stressed Environments
Section I - Link Protection
Section 2 - Anti-Interference
Section 3 - Encryption
Section 4 - Other Features

A discussion of standards to be developed after FS 1045 is beyond the scope of this paper.

Driving Forces

The demand for use of HF radio equipment is driven by the users who have experienced the fragility and the vulnerability to stress of the links that are employed to fulfill their communication needs. In particular, the Government agencies that are tasked with the mission of improving the robustness of our telecommunication infrastructure are the most interested in employing an HF radio network to supplement their other communication networks. The National Communications System (NCS) has been the leader in promoting the need for more durable systems, such as fiber optic links. In addition, NCS has supported efforts to provide alternate routes as backup links using the same or another medium.

The problem lies in the fact that a single, fixed link cannot be made totally immune to all stresses that threaten the installation. The result is a need for a medium that can be deployed quickly and with flexibility to restore a link that has been rendered out-of-service.

High-frequency radio fits this need, as many of the users have discovered in the last few years. The HF radio technology has advanced substantially, with the advent of integrated circuits; high-density, random-access memory (RAM); and digital processing of the transferred information. In addition, the groundwork has been laid for advanced digital information transfer techniques such as packet radio.

The HF radios two decades ago were operated by trained personnel who were expert in the operation, and sometimes maintenance, of the particular radio system employed. During the 1960s and 1970s, the use of HF radios waned. Radio operators were no longer needed and the profession literally disappeared, except for a few isolated cases where HF radios were still necessary.

The "new" interest in HF radios has created a need for radio operators again. However, this use of HF radios is intermittent, by the nature of the application. Radio operators are required only when the radios are deployed —thus the need for "user friendly" automated radios, a feature that could eliminate the need for trained operators altogether.

Implementation of automated radios was then deemed necessary for the applications that would satisfy the need for HF radio networks. Another essential element of the Nation's telecommunication system, deemed important by NCS, was interoperability—the ability for various Government and non-Government agencies to communicate with each other, especially when multiple agencies were responding to emergencies, such as disasters due to naturally-caused stress. The same concerns apply when responding to human-caused situations, where more than one military service would take an active part.

The Approach/Experimental Process

A typical industry development program assures that radios of like kind will be interoperable. If specified by the using agency, the vendor may be required to prove interoperability with other vendors' equipment. Users may obtain hardware from a number of different vendors with whom compatibility has been proven.

The HF radio standards should simplify this process, and possibly, eliminate the need for proving interoperability. The technical clarity of the standard must be such that more than one vendor can design radios (with ALE) according to the standard, and when deployed, the radios will be able to achieve a link with any other radio built to the standard.

At the onset, the HF Radio Subcommittee set a goal to achieve total interoperability within the HF arena. It was felt that the standards could be written in a way that this end result could be achieved. One of the important steps in the development process must be a thorough test of the hardware.

During development of Federal Standard 1045, there were several items to authenticate. First, a newly developed but untested waveform was offered as a state-of-the-art vehicle for HF automated radio functions. Tests must be performed to prove this concept. Second, two waveforms were offered as candidates for consideration and application as the "engine" for the ALE feature. The tests had to show conclusive proof that one waveform performed better than the other.

DEVELOPMENT PROCESS

The HF Radio Subcommittee first met under the leadership of ITS staff, in August 1987. During this session, a development process was derived that would assure that all concerns could be answered and the risks reduced. A diagram (flow path/function chart), shown in Figure 2, highlights the major functions in the development process.

The three circles in the flow diagram denote the function of three working groups that have performed significant functions in the pFS 1045 development process.

A first order of business was to determine the need —an assessment of the requirements of prospective users. The *Statement-of-Requirements Working Group (SORWG)* was formed to develop a document that would define the features necessary to satisfy the highest priority user requirements. A group of volunteers from the military and civilian Government agencies completed this task in less than two (2) months. The Federal Telecommunication Standards Committee (FTSC) approved the Statement of Requirements (SOR) as written by the SORWG.

The SOR was then used to provide the technical definition for use in design of prototype hardware. Prototype hardware was needed for proof-of-concept testing of the unverified waveform that was a derivative of a study performed by MITRE Corp, McLean, VA. This work was reported as a working paper entitled "Proposed Federal Standard 1045—High Frequency Automatic Link Establishment," by MITRE to its sponsor, NCS. The scheme was

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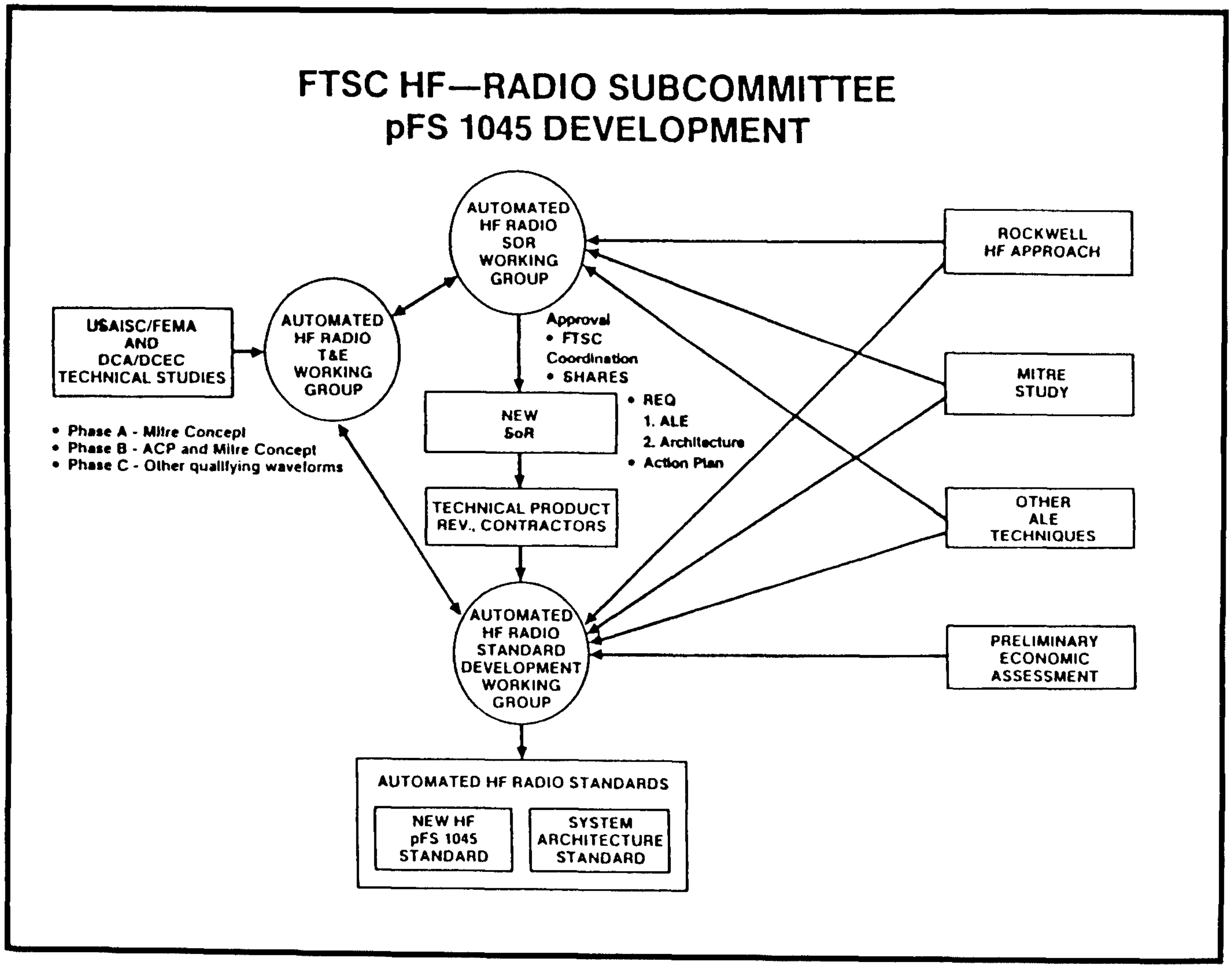

Fig 2—Standards development process flow diagram.

theoretically sound, but had not been modeled in hardware and tested.

A test plan, under the direction of the *Test and Evaluation Working Group (TEWG)*, was developed using the SOR as a guide for fixing the functions to be tested. In addition, the specification of performance parameters was being written in the form of a "draft" standard. In this case the draft standard was MIL-STD-188-141A. Later the same information was compiled in a format appropriate for Federal Standard 1045. These performance parameters were made a part of the test plan. The testing proceeded in three stages:

1. Laboratory proof-of-concept tests of the proposed waveform
2. Laboratory testing using simulated propagation paths
3. Over-the-air tests using field sites (test nodes)

The proof-of-concept tests and the propagation path tests were performed using Watterson-model-based simulation equipment.[1,2] The over-the-air tests were carried out using four nodes. Nodes were selected to provide short- and long-hop paths and long north-south and east-west paths. Figure 3 shows the location of the four nodes.

The *Standards Development Working Group (SDWG)* was given the responsibility for writing the standard. As mentioned earlier, the writing process for the standard started during the technical definition phase of develop-

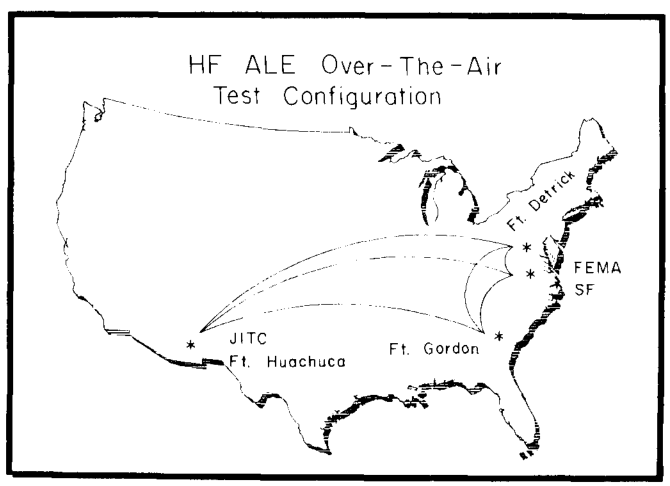

Fig 3—Locations of over-the-air test nodes.

[1]Reference appear on page 7.

ment. The standard is actually a specification [with additional details] but is a more highly developed document.

The SDWG used the test results to polish the draft standard (specification) by pointing out areas that needed clarification or performance limit adjustment. When the standard was finally ready for formal coordination, it was a product of several iterations of development and fine tuning.

Technical Definition/Prototype Hardware

The concepts proposed for FS 1045 were broken down into features as stated in the SOR. These features were stated technically in a specification. This specification defined, in technical language, the limits on parameters that were used to design the hardware, firmware, or software necessary to perform the functions. It is imperative that the designers of the hardware be involved in this technical definition. The industry suppliers are the designers in most cases. Participation by industry representatives, at this point, is important. However, it is also important that the specification does not favor one vendor over another and that it does not limit the flexibility of implementation.

Once the technical definition was complete, a vendor was funded to model the features into hardware using the specification. This hardware model, in 1989, usually includes some firmware and software. The vendor is allowed to select the implementation method, based upon the vendor's design philosophy and the talent and experience of the staff. It should be pointed out that another vendor may have chosen another method of implementation with equal success in the final product.

For the test vehicle, the proposed FS 1045 model was embedded in the Harris Corp HF radio adaptive controller.[3] The Harris radio system was used because the US Army Seventh Signal Command, Ft Ritchie, MD, was able to make the radios available for the project. FEMA, the agency that needed the prototype hardware for proof of concept testing, is a user of Harris HF radio equipment and funded Harris Corp to perform the design modifications necessary for the tests.

The ALE controller was added as a separate functional system, embedded as a hardware module within the radio's adaptive controller chassis. See Figure 4 for a functional block diagram showing this configuration.

Validation Tests

As noted earlier, the validation tests were performed in three steps. Each of these test steps was completed at the most convenient and appropriate location. This was required because several Government agencies were funding the project and because of equipment availability.

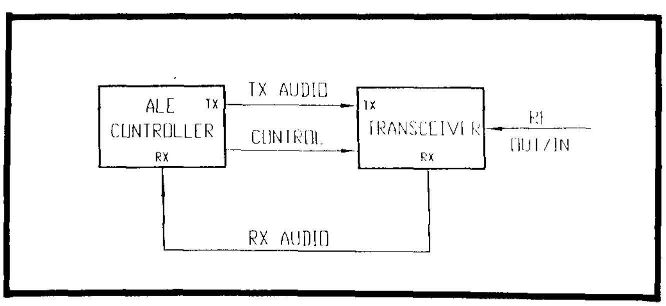

Fig 4—Block diagram of prototype ALE HF radio system.

The "Proof of Concept" tests were performed at the vendor (Harris Corp) in Rochester, NY. This test was a laboratory test, using the vendor's HF simulator equipment. The HF simulator used for this test was correlated with the simulator used later for laboratory testing of the radios to ensure that the tests were valid. The primary reason for this proof of concept test was to demonstrate feasibility of the untested waveform proposed for consideration and integration into FS 1045.

The second step was a comparison test of the two proposed waveforms: (1) the waveform fielded by Rockwell/Collins, and (2) the waveform designed by MITRE Corp. A determination of performance was the primary reason for the tests. A measure of the "probability of linking" was calculated from data collected with a range of propagation parameters. The propagation channels were simulated using CCIR definitions for "good" and "poor" channels and an industry standard for the Gaussian channel. Over-the-air testing was then performed using the four test nodes discussed earlier. This test was also a comparison test between the two waveforms.

Developing the pFS 1045

The standard was then patterned after the MITRE study-based prototype hardware that was found to perform the best during the comparison tests. This result was expected because the MITRE concept was derived by integrating the best ideas from several manufacturers, and the SDWG added new advanced concepts.

A proposed standard was then offered to an open assembly of Government and industry representatives for comment. These comments were then used to improve the draft. A final draft standard was completed and presented to the Federal Telecommunications Standards Committee for approval.

Benefits Analysis

The benefits of this standard can be translated into improvements in interoperability and in equipment cost reduction. A survey taken by ITS shows that the users estimate that about 65 percent of all radios purchased in the next five (5) years will use ALE. If this comes to pass, it will have a significant impact on the interoperability among Government organizations.

The market size is estimated to be in excess of $2.5 billion during the next five (5) years. Potential savings of 5 to 25 percent are projected by the users. These savings will result for several reasons; standardized design, elimination of proprietary designs, and volume production.

An additional benefit will be realized when these standards are adopted by international standards organizations. This action will escalate the benefits described above.

Successes

Many successes have been recorded during the adoption of FS 1045. The most satisfying accomplishment has been to develop a cohesiveness among the user and supplier organizations. This standard is a product of the efforts of both groups—all parties are in agreement with the concept and have all voted for its approval.

A standards development process has been developed, tried, and proven during the writing of FS 1045. All agree that this is a major accomplishment. This process, as shown in Figure 5, can be used for development of future Federal standards.

Conclusions/Recommendations

The primary goal of this Federal standards effort was to produce an Automatic Link Establishment standard that would enhance interoperability of HF equipment owned by Government and military organizations. We conclude, based upon the positive response from users and suppliers, that this goal will be met.

This standard has been produced in a timely manner, such that the greatest number of HF radios can be procured with the ALE feature. The long-term benefit will be improved interoperability.

The cost benefit should not be overlooked. A reduction in cost of each radio could reach 25 percent, as projected by users and suppliers of radios. The savings to the Government could be significant, considering the fact that the estimated market size exceeds $2 billion.

The process to develop the related Federal standards is being expedited, based upon the potential benefits and perceived cost savings to the Government. This endeavor is being received enthusiastically by the military and civilian Government agencies.

References

[1]Watterson, C.C. (1979), J.R. Juroshek, and W.D. Bensema (1970), "Experimental confirmation of an HF channel model," *IEEE Trans. Commun, Technol. COM-18*, pp 792-803.

[2]Watterson, C.C. (1979), "Methods of Improving the Performances of HF Digital Radio Systems," *NTIA-Report-79-29*, USDOC, Boulder, CO, Oct.

[3]Certain commercial equipment and software products are identified in this report to adequately describe the design and conduct of the research or experiment. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

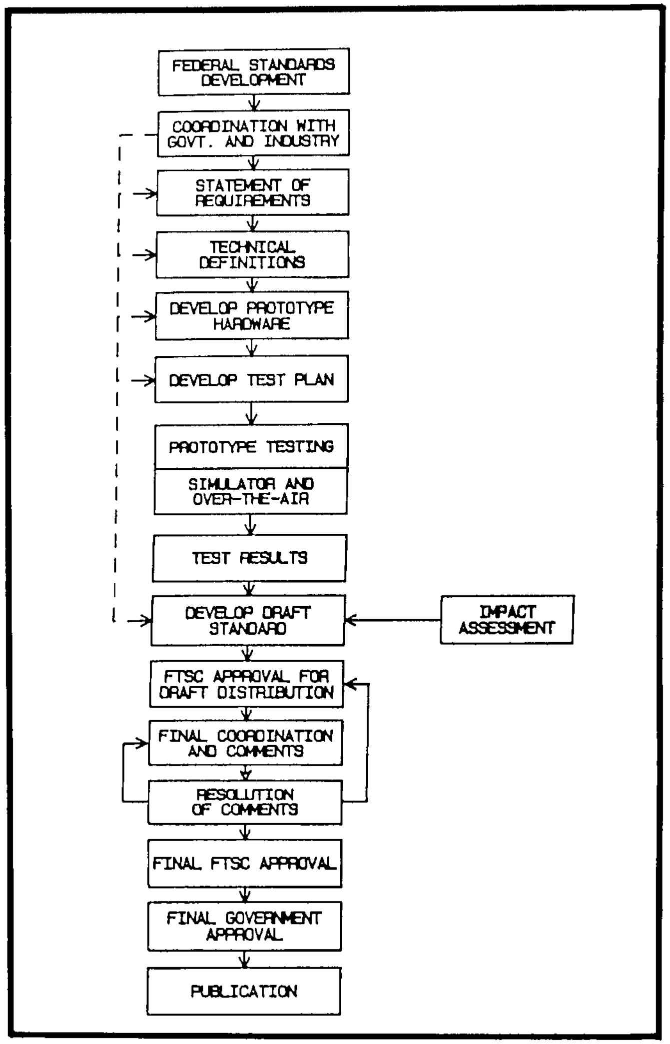

Fig 5—Block diagram of the Federal standards development process.