

The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

Part I: The National Communications System, The Federal Standards Development Process, and the Basic Definition of Federal Standards 1045 through 1054

Significant interest and activity are rapidly developing in the HF ALE radio arena. Equipment and knowledge of the technology are becoming available which allows experimentation and use of this new mode.¹ Stand-alone ALE controllers (modems) are now available to amateurs interested in ALE. The use of ALE is an exciting new technique for passing digital traffic in parts of the spectrum which are typically unusable for voice traffic. Operating "down-in-the-mud" can be fun!

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Introduction

The development and implementation of Federal Standard 1045 (FS-1045), "HF Radio Automatic Link Establishment" has revolutionized HF radio communications by utilizing automated, digital signal transmission techniques.² This standard provides the foundation for an entire family of HF radio standards which functionally, specifies the automation of these radios. The features included in this family of standards make these radios automatically adaptive to the ever-changing HF propagation conditions—thus the radios are termed adaptive HF radios. The HF Radio Automatic Link Establishment (ALE) functions are standardized in FS-1045. FS-1045 provides the standardized functions for a linking process, including the emission of a call, a response, and an acknow-

ledgement signal. The emission waveform contains address information that will selectively alert a station and will trigger a response from that station if the station is operational (either scanning or monitoring a specified frequency). The "functional standard" specifies the required protocols, timing, and technical definitions, but leaves implementation to the innovation of the equipment manufacturer. The technical details of this standard are described in the May 1992 issue of *QST*.³

A significant national effort is focused on developing and testing a family of functional standards for automated HF radio systems. When fully developed and implemented, these standards will substantially improve radio communications efficiency and interoperability within and among civilian Federal agencies, emergency

preparedness organizations, Amateur Radio operations, and the US military departments. These standards will also enhance competition and promote new product development in the US telecommunications industry, which should advance the vendors' positions in the world trade market. This will also lower the cost of radios and will make them more affordable by amateurs.

A series of articles has been written for publication in *QEX* by various individuals involved in the development, writing, and testing of the Federal Standards for adaptive HF radios. The titles and basic contents of this series are detailed in Table I.

Basic ALE Radio Functions

By now you may be wondering, what can ALE radios do and how do they work? Fig 1 illustrates the similarities

¹Notes appear on page 8.

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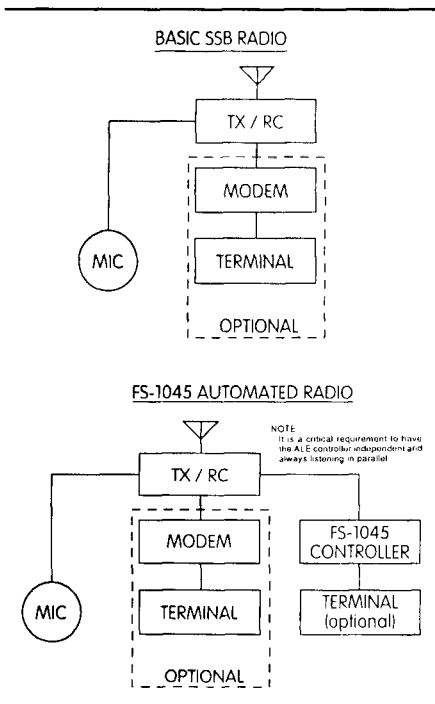


Fig 1—Basic SSB radio with optional terminal compared to an FS-1045 automated radio with optional terminal.

and differences associated with a typical single sideband (SSB) HF radio and a Federal Standard 1045 capable radio. The FS-1045 controller is basically a robust modem which controls the HF SSB radio to which it is attached.

The basic ALE unique functions are summarized in Table II. Automatic Link Establishment is accomplished by passing 8-ary FSK (8 audio-frequency tones) through the audio passband of a programmable SSB radio. ALE radios can be programmed to scan up to 100 frequencies, but typically 10 frequencies are more than adequate to cover the HF band. The calling radio stays on each frequency for only 200 milliseconds which means that all ten frequencies can be scanned and a successful link made with a scanning receiving station in much less than a minute. This will greatly reduce the HF spectrum "pollution" of calling CQ, CQ, CQ... and then trying it over again manually on various other frequencies until a suitable link is made.

The remaining functions are being developed and will be implemented in future standards within the HF radio family of proposed Federal Standards (pFS) as shown in Table III. Further information on these standards will appear in later articles in this series.

ALE Operating Rules

ALE radios must obey strict operating rules in order to function properly. The following specific ALE operational rules are listed in order of precedence. These rules must be strictly adhered to for the ALE radios to successfully interoperate.

1. Independent ALE receive capability (in parallel with any others) (critical)
2. Always listens (for ALE signals) (critical)
3. Always responds (unless deliberately inhibited)
4. Always scans (if not otherwise in use)
5. Never interferes with active ALE channels (unless priority or forced)
6. Always exchanges Link Quality Analysis (LQA) with other stations when requested (unless inhibited), and always measures the signal quality of others
7. System responds in preset/derived/directed time slot (net/group/special calls)
8. Always seeks (unless inhibited) and maintains track of connectivity with others
9. Linking ALE stations employ highest mutual level of capability
10. Minimizes time on channel
11. Minimizes power used (as capable)

The Standardized Levels of HF Radio Interoperability

Fig 2 illustrates the standardized levels of HF radio interoperability and the Federal Standards with which they are associated. The higher the standardized level number (on the diagram) the more advanced and difficult the level of automation which is required to achieve that particular function. The diagram also contains a representation of the families of Federal Standards which encompass these functional standardized levels. It is difficult to divide these functional levels into distinct, separate numbered standards. The listed functional levels interact in several instances and cannot be clearly delineated in software and hardware during implementation. The MITRE Corporation in Washington, DC, performed considerable research and development on this subject over the period of several years.^{4,5,6} This has formed a strong foundation for the development and standardization of advanced technology adaptive HF radios.

HF radios which embody the Federal Standard 1045 functions are capable of performing the standardized levels 1 through 4 and a portion of level 7.

Improved Operating Efficiency

ALE HF Radios which embody Federal Standard 1045 do not require well-trained, experienced operators to allow rapid, high-quality communications. These radios are capable of scanning up to one hundred preprogrammed frequencies, analyzing the quality of the propagation path over each to the desired station or stations and automatically linking in a matter of seconds or minutes. These radios have been shown to link successfully and pass data over channels with S/N levels 10 dB below detectable voice levels.⁷ These capabilities provide for a much more efficient use of the crowded frequency spectrum. Further details of the ALE waveform and the linking process appeared in May 1992 *QST*. The standardized radio functions also result in equipment cost reductions, and predictable interoperability among different brands of equipment, which can save an estimated 25% procurement cost per radio. The technological and economic impact assessment of this standard was performed by NTIA/ITS.⁸ This document illuminates

Table I

The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

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| Part I: | The National Communications System, the Federal Standards Development Process, and the Basic Definition of Federal Standards 1045 through 1054. |
| Part II: | A Compact Disc for Testing HF ALE Radios. |
| Part III: | Where are the Federal Standards for HF ALE Radio Networking Going? |
| Part IV: | Network Simulation for the Radio Amateur. |
| Part V: | An Amateur's Practical Approach to HF ALE Systems. |
| Part VI: | Federal Standard 1049: The Future of HF ALE Operation in Stressed Environments. |

the response from government and industry and summarizes the pertinent facts. The common use of radio systems utilizing the FS-1045 family of Standards will greatly enhance the nation's telecommunications infrastructure for both routine and emergency traffic, and will eventually enhance amateur communications.

Current Activities

Three proposed Federal Standards are currently in the process of final approval and publication: 1) FS-1045A, 2) FS-1046/1, and 3) FS-1049/1. FS-1045A is a revision of FS-1045, which provides updating and enhancement to the original standard. FS-1046/1 is the basic automatic networking "building block" of the family, and FS-1049/1 provides the protection function for ALE radios during the linking process. A technological and economic impact assessment of these three proposed standards was performed by NTIA.⁹

Background Information

The National Communications System was established on August 21, 1963, by a Presidential Memorandum entitled "Establishment of the National Communications System."¹⁰ On April 3, 1984, President Reagan signed Executive Order (E.O.) 12472 "to provide for the consolidation of assignment and responsibility for improved execution of national security and emergency preparedness telecommunications functions."¹¹ This Executive Order supersedes the August 21, 1963, Presidential Memorandum. It was again updated by the President as E.O. 12656 on November 23, 1988.¹²

The NCS is a confederation in which Federal departments and agencies participate with their telecommunications assets to assist the President, the National Security Council and the Director of the Office of Science and Technology in meeting their need for National Security and Emergency Preparedness communications for the Federal Government under all circumstances, including crisis or emergency.

The principal assets of the NCS include telecommunications networks of the following Departments and Agencies: Departments of State, Defense, Health and Human Services, Justice, Treasury, Agriculture, Interior, Commerce, Energy, and Transportation (which includes networks of the Fed-

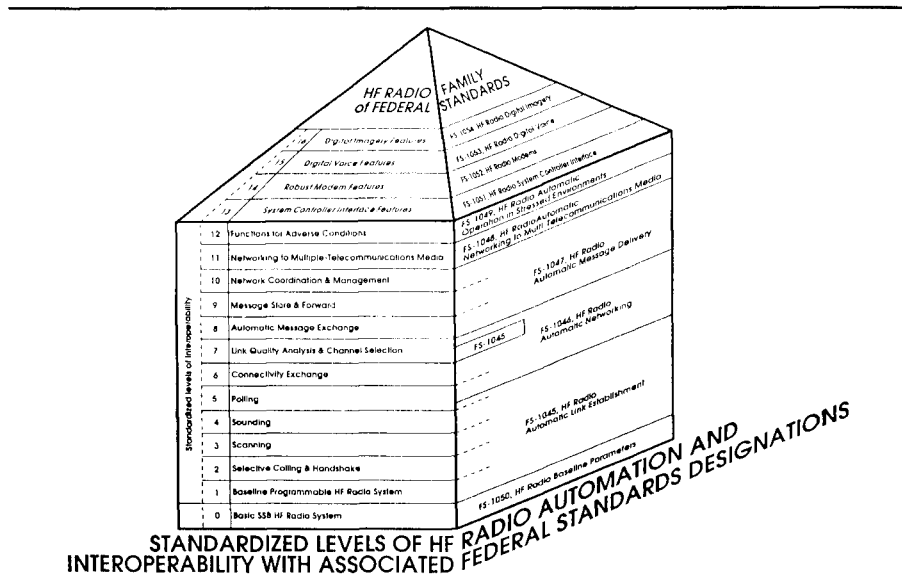


Fig 2—Pictorial diagram illustrating the standardized levels of HF radio interoperability and the federal standards with which they are associated.

eral Aviation Administration and the United States Coast Guard) Veterans Affairs, the Federal Emergency Management Agency, the US Information Agency, the National Aeronautics and Space Administration, the General Services Administration, the Central Intelligence Agency, National Security Agency, and the National Telecommunications and Information Administration. There are also four participating Agencies: the Nuclear Regulatory Commission, United States Postal Service, Federal Communications Commission, and the Federal Reserve System. Fig 3 illustrates these relationships.

The Concept: A Coherent National Telecommunications System

These assets comprise the bulk of the long-distance telecommunications resources of the Federal Government. Telecommunications facilities are planned, funded, and operated by the parent agencies to satisfy their respective mission requirements; however, through joint planning, standardization, and other coordinated management activities of the NCS, they are available to satisfy national requirements transcending those of the individual operating agencies. The objective is to ensure that essential federal telecommunications resources are improved progressively, and can be inter-operated so that the aggregate functions as a coherent system under

all conditions, particularly those of crisis or emergency.

Policy and Management Functions

Policy direction for the development of the NCS stems directly from the National Security Council, as set forth in Executive Order 12472, and National Security Decision Directive 97 (NSDD-97), "National Security Telecommunications Policy."¹³ The Director of the

Table II

Summary of HF Radio ALE Functions

1. ALE Protocol Tones Pass Through SSB Radio Audio Pass Band
2. ALE Digital Modem Provides a Low Speed, Robust Device For Selective Calling and Data Transmission
3. ALE Modem Automatically Selects "Best Available" Channel Based on Link Quality Data Stored in ALE Memory
4. ALE Radio Automatically Establishes and Confirms Links Upon Operator Command
5. ALE Radios Can: Transfer Data, Do Error Checking, Do Networking, Relay Messages, and Other Special Functions

Office of Science and Technology Policy (OSTP), Executive Office of the President, is responsible for directing the exercise of the war power functions of

the President under Section 606 of the Communications Act of 1934, as amended. E.O. 12472 designates the Secretary of Defense to serve as the

Executive Agent for the National Communications System. NCS is responsible for ensuring that unified operations and technical planning are conducted to afford a highly effective and responsive system to meet the needs of the Federal Government. The major functions delegated to the Manager-NCS by the Executive Order include those pertaining to coordination, planning, standards, test, and evaluation.

The Secretary of Defense has designated the Director of the Defense Information Systems Agency (DISA) to serve as the Manager of the NCS. In order to carry out the NCS management responsibilities, an Office of the Manager-NCS, was established. This office is separate and unique because its authorities emanate directly from the Executive Office of the President to the Executive Agency, NCS. NCS is also unique within the Federal Government because considerable personnel support for the office is provided by the member organizations of the confederation (see Fig 3). The member organizations select members of their staff to work full time for the Office of the Manager, NCS, and detail them for a minimum of two years.

Working Relationships: Operating Organizations' Roles

The Operating organizations of the NCS play a central role in the formulation of telecommunications policy and the solution of mutual problems by means of representation in NCS study groups, ad hoc committees, and permanent committees formed by the Manager, NCS. Depending on the nature of the task, the Operating Agencies provide personnel with the needed skills to serve on the working groups and committees along with members of the Manager's permanent staff. The Federal Telecommunication Standards Program (FTSP) is among functions assigned by E.O. 12472 in support of the mission of the NCS. The FTSP is clearly vital to the successful accomplishment of this particular aspect of the NCS mission by its emphasis on the development of standards to facilitate interoperability of the NCS component networks.

The Federal Telecommunication Standards Program

The Federal Telecommunications Standards Program (FTSP) was initi-

Table III

The HF Radio Family of Federal Standards

<i>Standard Number</i>	<i>Title</i>
FS-1045	Telecommunications: High Frequency Radio Automatic Link Establishment.
pFS-1045A	Telecommunications: High Frequency Radio Automatic Link Establishment (revision of FS-1045).
pFS-1046/1	Telecommunications: High Frequency Radio Automatic Networking, Section 1: Basic Networking - ALE Controller
pFs-1046/2	Telecommunications: High Frequency Radio Automatic Networking, Section 2: Advanced Networking - ALE Controller.
pFS-1046/3	Telecommunications: High Frequency Radio Automatic Networking. Section 3: Advanced Networking - Network-Layer Controller.
pFS-1046/4	Telecommunications: High Frequency Radio Automatic Networking, Section 4: Optional Advanced Networking Features.
pFS-1047/1	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 1: Automatic Message Exchange.
pFS-1047/2	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 2: Automatic Message Exchange with Store & Forward.
pFS-1047/3	Telecommunications: High Frequency Radio Automatic Message Delivery, Section 3: Network Coordination and Management.
pFS-1048	Telecommunications: High Frequency Radio Automatic Networking to Multiple-media.
pFS-1049/1	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 1: Linking Protection.
pFs-1049/2	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 2: Anti-interference.
pFS-1049/3	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 3: Encryption.
pFS-1049/4	Telecommunications: High Frequency Radio Automatic Operation in Stressed Environments, Section 4: Adaptive Operation.
pFS-1050	Telecommunications: High Frequency Radio Baseline Parameters.
pFS-1051	Telecommunications: High Frequency Radio System Controller Interface.
pFS-1052	Telecommunications: High Frequency Radio Modems.
pFS-1053	Telecommunications: High Frequency Radio, Digital Voice.
pFS-1054	Telecommunications: High Frequency Radio, Digital Imagery.

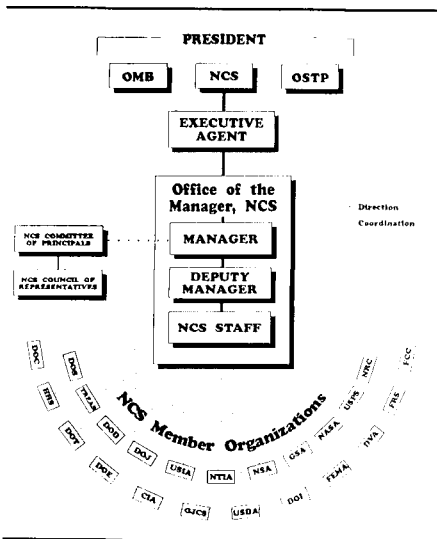


Fig 3—Organizational chart of the National Communications System showing the direct authority from the Executive Branch of the government.

ated in 1972.¹⁴ The scope of the NCS's assignment under the Federal Standardization Program is to develop Federal standards which either contribute to the interoperability of functionally similar Federal telecommunications networks or to achieve a compatible, efficient, and economical interface between such networks and appended computer terminals. The emphasis of the FTSP is on the development of standards to facilitate interoperability of the NCS member networks. All standards resulting from the FTSP are coordinated, approved, and published in accordance with the GSA-managed Federal Standardization Program, or the National Institute of Standards and Technology (NIST) Federal Information Processing System (FIPS) publications program, whichever is appropriate to the particular standard in question. The Manager of the NCS has the overall responsibility of the FTSP, however the Assistant Manager for NCS Technology and Standards is assigned the daily management of the FTSP.

The Federal Telecommunications Standards Committee

The Assistant Manager for NCS Technology and Standards also Chairs the Federal Telecommunications Standards Committee (FTSC) (see Note 14). The FTSC consists of senior telecommunications staff members from participating Federal Agencies. This committee, which

meets monthly, determines the relevance and priority of standardization proposals, recommends positions which should be supported by Federal Government members of national and international standardization committees, and rules on the technical adequacy of draft Federal Telecommunications Standards for formal coordination with Government Agencies and industry. The NCS Office of Technology and Standards also provides leadership and members for a number of inter-agency, industry, national, and international standards committees. These committee members (and officers) consist of NCS staff members and program support staff from other government agencies such as the NTIA/ITS. The committees are actively engaged in the identification and development of concepts and ideas which may be accepted in whole or in part as Federal Standards.

The HF Radio Subcommittee & Its Working Groups

The FTSC has generated several Subcommittees which develop Federal Standards to fulfill specific areas of need. Fig 4 illustrates the method by which the HF Radio Subcommittee functions. Working members were solicited from the 23 Federal Agencies. The subcommittee developed the infrastructure which consists of three Work-

ing Groups (WGs): 1) the Statement of Requirements WG (SORWG); 2) the Test and Evaluation WG (TEWG); and 3) the Standards Development WG (SDWG).

Federal Standards Development, Coordination, & Approval Process

The NTIA/ITS staff has conceived a rather detailed Federal Standards Development Procedure which works very well in the development of "Advanced Technology Standards." Fig 4 depicts the functions and relationships of the HF Radio Subcommittee and its three working groups. The Statement of Requirements Working Group (SORWG) functions first in this process, to determine the requirements which must be met in the finished standard. These requirements are gathered from the government departments and agencies which will be the users of the equipment that is built to conform to the standards being developed. Significant attempts are made to determine the real programmatic requirements from the organizations which will be the users of the equipment for the next decade. These requirements are then transformed into technical definitions from which prototype hardware can be built. The Test and Evaluation Working Group (TEWG) functions to develop procedures for a set of minimum-but-adequate tests. These tests are de-

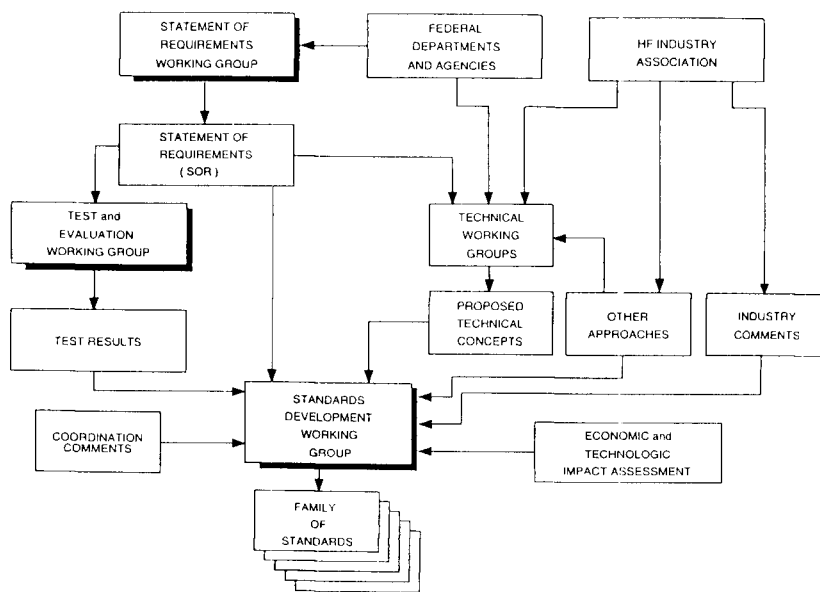


Fig 4—Diagram of the HF Radio Subcommittee Process illustrating the functions of the Working Group.

signed to determine the feasibility of implementing the standard and to prove the concept of the written standard. The test program is intended to uncover any problems within the standard and the process of embedding it into practical, interoperable hardware. The results of the testing program are studied and summarized in the form of a report which is then utilized by the Standards Development Working Group (SDWG). The SDWG then develops a "functional" standard which can be used by industry to build hardware that conforms to the standard and is therefore inter-operable with equipment constructed by other manufacturers. A functional standard specifies key features, but allows room for the vendors to develop and install their own innovative features in addition to those specified. This tends to stimulate competition and enhance the product lines into user friendly highly capable hardware. The SDWG develops a draft standard based on the requirements, the test results, and a technologic and economic impact assessment. This draft standard is then announced (after approval by the FTSC) via the Federal Register to obtain comments from public, industry and Government representatives over a 90-day comment

period. Comments of substance are resolved and incorporated into the final draft standard which is then submitted to the FTSC for approval and final submission to GSA or NIST (as appropriate) for final approval and publication.

Summary

A national need was identified for the continuous and interoperable communications for the Federal Government under all conditions. The National Communications System was formed to provide and coordinate that capability. The development¹⁵, testing (see Note 7), and publication (see Note 2) of Federal Standards providing interoperability has been one of the primary means of achieving this mission.

The forthcoming parts of this series of articles will continue to present information on other aspects of the family of Federal Standards for automated HF radios. Further details on the availability and application of ALE in the amateur radio service will be presented.

Acknowledgements

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ITS). The authors would like to express their sincere appreciation to all those who had a hand in conceiving, developing, testing, and improving the nation's telecommunication infrastructure through the development, implementation, and use of the Automated HF Radio Standards and equipment described in this series of articles. This work of many engineers, technicians, and operators has revolutionized the field of HF Radio Communications. The authors would also like to thank John Harman and Bill Ingram for the graphics which appear in these articles.

Notes

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FEDERAL STANDARDS DEVELOPMENT PROCESS

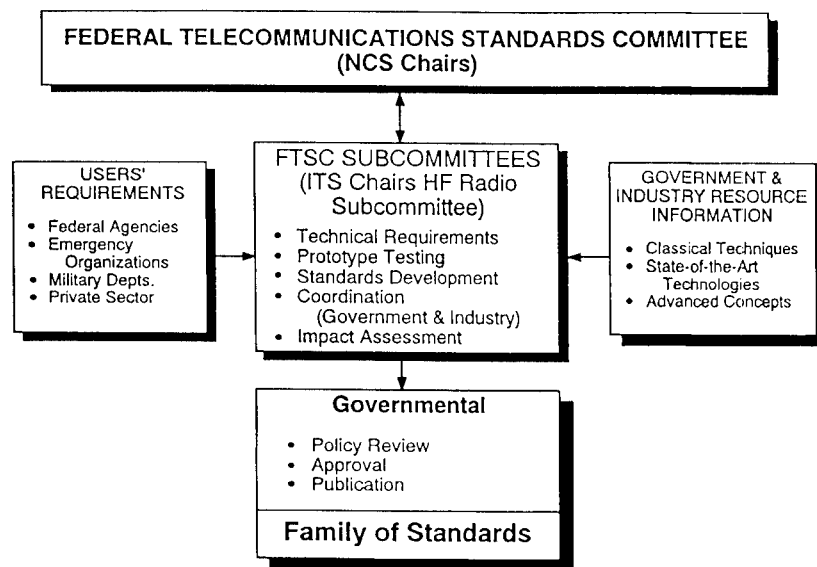


Fig 5—Diagram illustrating the methodology by which the HF Radio Subcommittee functions.