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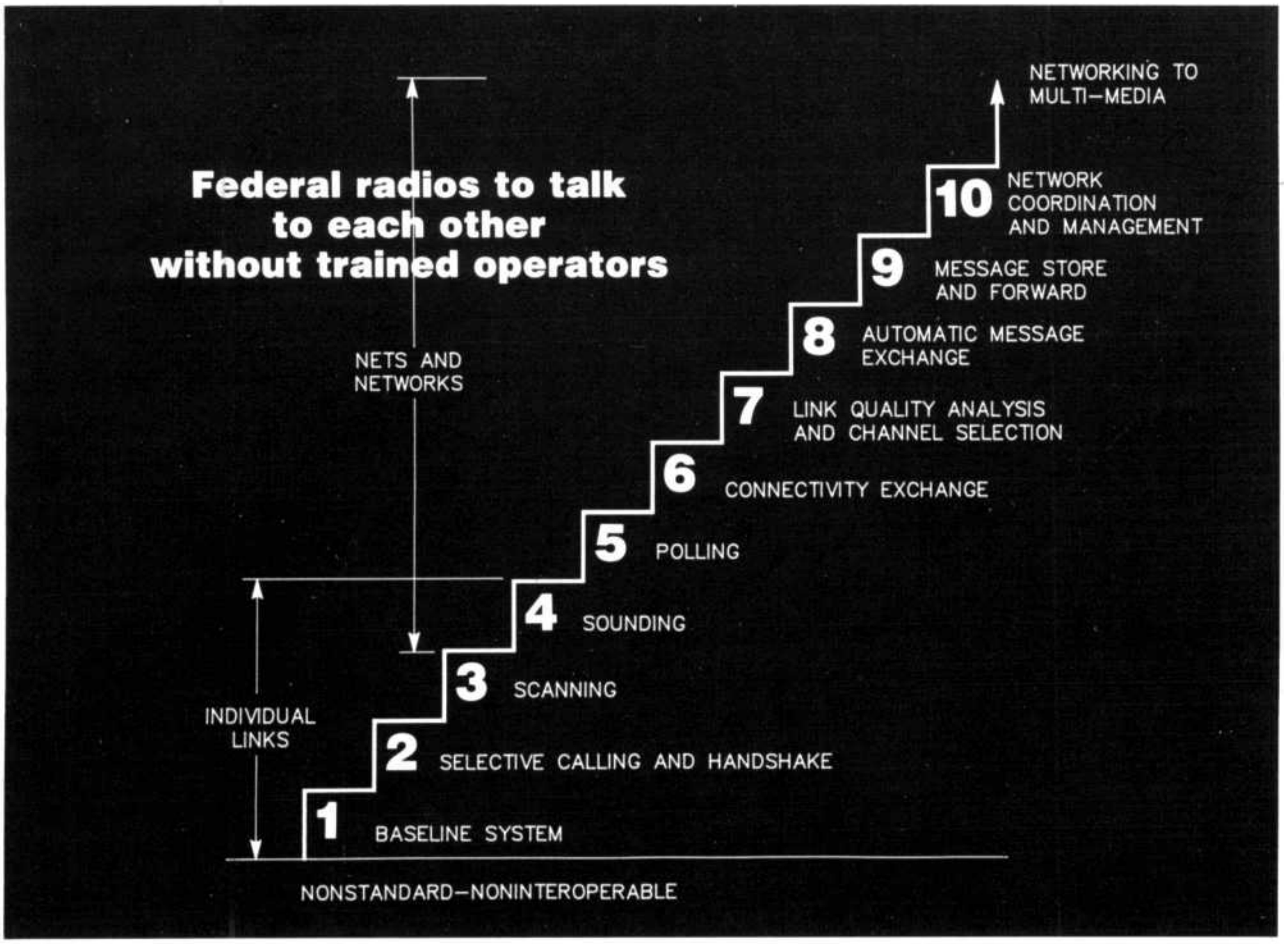
QEX 95

ARRL Experimenters' Exchange

JANUARY 1990



QEX: The ARRL
Experimenters' Exchange
American Radio Relay League
225 Main Street
Newington, CT USA 06111

Non-Profit Org.
US Postage
PAID
Hartford, CT
Permit No. 2929

QEX (ISSN: 0886-8093) is published monthly by the American Radio Relay League, Newington, CT USA.

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Subscription rate for 12 issues:
In the US by Third Class Mail:
ARRL Member $10, nonmember $20;

US, Canada and Mexico by First Class Mail:
ARRL Member $18, nonmember $28;

Elsewhere by Airmail:
ARRL Member $38, nonmember $48.

QEX subscription orders, changes of address, and reports of missing or damaged copies may be marked: *QEX* Circulation.

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THE AMERICAN RADIO RELAY LEAGUE, INC

The American Radio Relay League, Inc, is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communications in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

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1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio field
3) support efforts to advance the state of the Amateur Radio art.

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT 06111 USA. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in recent editions of *The ARRL Handbook*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

Empirically Speaking . . .

The May *QST* article entitled "The Great 1989 HF Packet Design QUEST" was the announcement of a program to develop techniques to improve the performance of HF packet radio. The program is now underway, and it's time for an update.

The ARRL applied for, and received in early October 1989, a two-year, $10,000 grant from the Federal Emergency Management Agency (FEMA) to underwrite this work. In addition, the ARRL has two other funds (the Starr Technology Fund for improvements in HF packet radio, and the Rinaldo Technology Fund for broader research and development including HF packet radio) with balances of a little over $3,000 each. While these Technology Funds are considered adequate to realize an improvement in HF packet radio technology in the next year or two, they are not adequate for the long term. Of course, the League welcomes contributions to these already established funds. With more funding, we will be able to support work done by volunteer labor without having the volunteers foot the entire bill for out-of-pocket costs done to advance the state-of-the-art of Amateur Radio.

At the ARRL Computer Networking Conference in Colorado Springs, the Digital Committee heard a report of HF packet receiving tests by Steve Hall, WM6P, which gave strong support to the use of diversity reception. Recently, Steve, on behalf of a team of co-investigators, made a proposal to the Digital Committee for a grant to pay for part of the costs needed for hardware to conduct further diversity tests. While Steve's proposal came in before we made a formal Request For Proposals (RFP), the Digital Committee is giving it early consideration.

In addition, we invited, and received, a number of resume's and white papers from individuals and groups interested in participating in this program. As a next step, we are now ready to issue a formal RFP soliciting proposals for specific research and development in the four areas of study already identified by the

- Spectrum management (reduction of collisions)
- Diversity reception (reduction of multipath effects)
- Modem design (improve signal performance in the presence of interference and noise)
- Protocol design (improve robustness of link layer)

In addition to the RFP document, there will be other guidance for prospective participants concerning standard test conditions so that there is some reference against which to measure improvements in performance over what we are using today on HF packet.

Along with expressions of interest in participating, we have been receiving a number of letters with helpful material such as bibliographic references, ideas on what will and won't work, and the like. You will find some of this material in this issue, and recent issues, of *QEX*, and we'll print more as we receive them. Some people have written us to say that they can't participate in the program because of the press of other business, but would like to help in various ways. The other observation is that the material is well-thought-out and coming from hams with excellent engineering track records.

This is the time for amateur experimenters to move HF packet technology ahead. The Amateur Radio Service needs it. Also, we know by experience that our improvements in the performance of HF packet radio will be applied to other radio services. Obviously FEMA, for one, believes that to the tune of $10,000.

If you believe you can make a contribution through participation in the program, please contact Lori Weinberg to be added on the mailing list for the RFP. If you can't contribute technically but would like to support this work, consider a donation to either of the ARRL Technology Funds named above. The ARRL is a nonprofit 501(c)(3) organization and donations to it are tax-exempt to the extent allowed by the Internal Revenue Code. —*W4RI*

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)

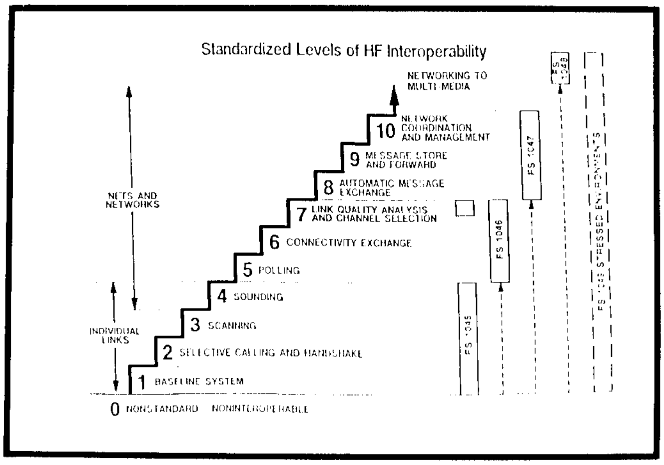

Fig 1—Functional levels of automated HF radio systems.

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

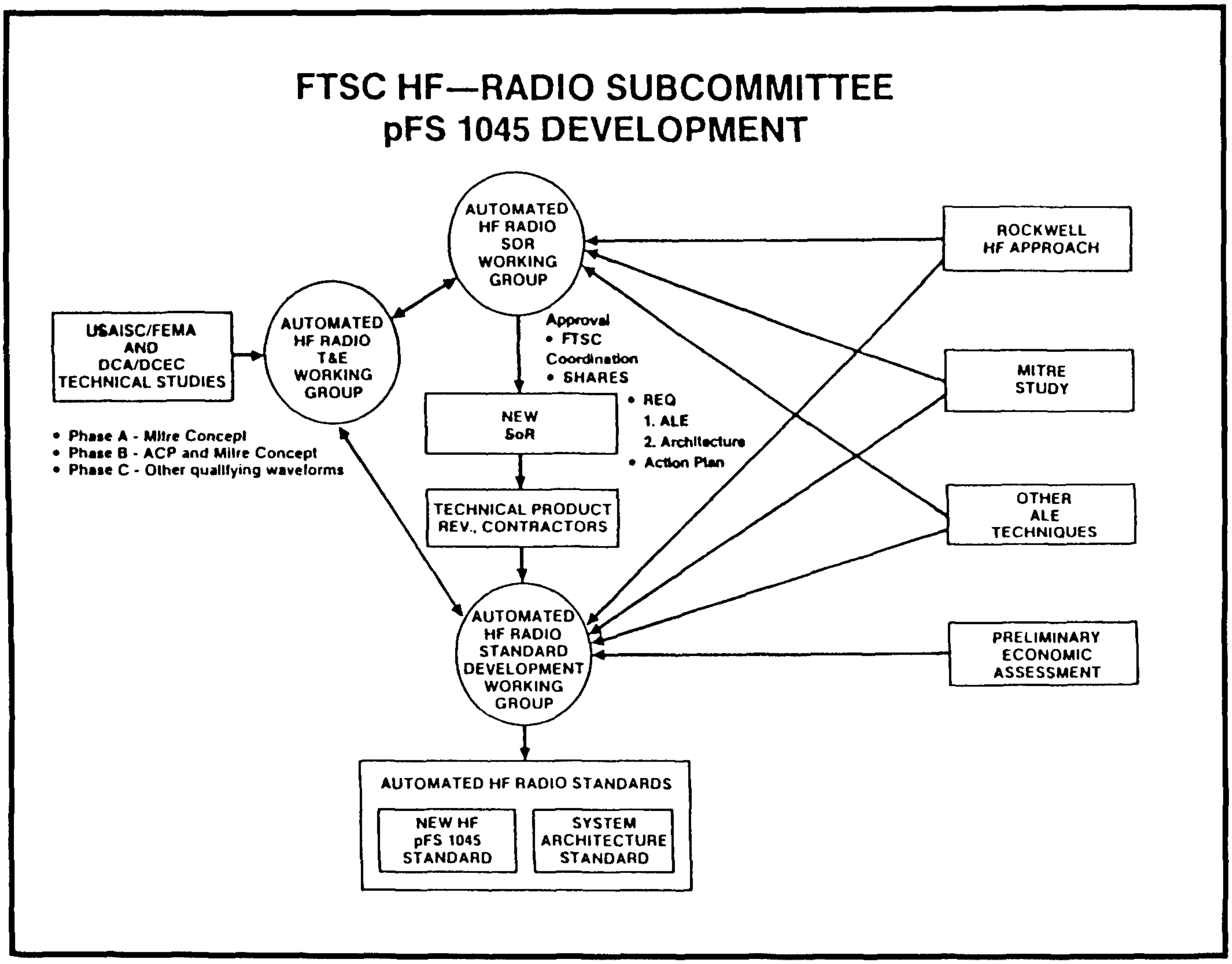

Fig 2—Standards development process flow diagram.

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-

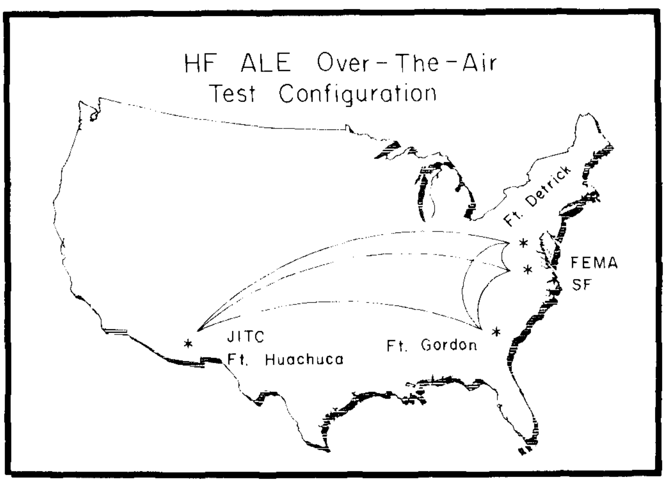

Fig 3—Locations of over-the-air test nodes.

[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.

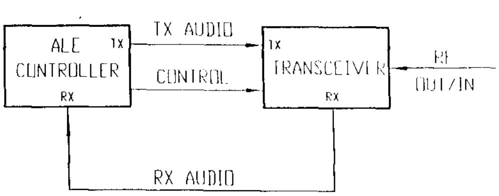

Fig 4—Block diagram of prototype ALE HF radio system.

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.

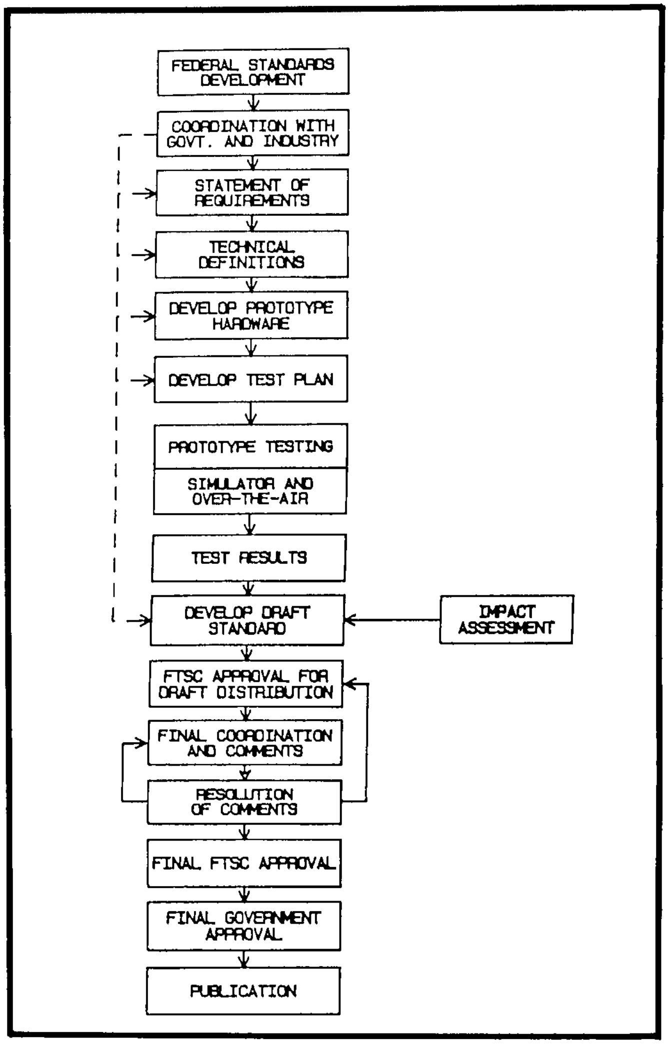

Fig 5—Block diagram of the Federal standards development process.

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.

1.3 GHz Measurements Using Home-Brew Gadgets

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Several times I have heard the statement, "It's fortunate that most microwave experimenters have access to commercial test equipment." Actually, that could be interpreted as, "a prerequisite for a microwave experimenter is that he have access to commercial test equipment." I'll admit, there are constraints in accomplishing microwave testing that makes a person think twice before tackling an experimental project. However, there are basic test procedures together with simple test devices that, when properly applied, will provide accurate data. The following is a description of such procedures and how to build the necessary supporting test assemblies. This includes a 50-ohm blackbody load with a peak voltage readout, a device for measuring SWR, and a thermal-type power measurement assembly. Also included are methods and test hardware descriptions for evaluating spurs and spurious responses. All test gadgets are of the simple home-brew variety using no special components.

Test Procedures

The primary concern is to measure the character of a signal at a particular frequency. Harmonic content, low-energy spurs at the frequency of interest, and spurious responses due to an instability condition will cause measurement errors. The effect is compounded by the fact that almost all measurements depend upon a peak-reading diode detector readout and interpretation of this output usually assumes a sinusoidal input signal. In general, this device reads the sum of all signals on the output and the conditions listed above will result in an error by adding to the peak-reading output. As an example, a low-energy spur can increase the apparent output of an amplifier, as indicated by a peak-reading device, to a value that is impossible to relate to amplifier efficiency. It has been my experience that this dirty signal effect is the major cause of measurement error. Problems of this type are difficult to define without the use of a spectrum analyzer. However, the following procedures together with simple test devices go a long way in confirming a clean source signal.

Step 1 Detecting Gross Abnormalities—A nulling-type Lecher wire system is used to confirm reasonable source purity. The system consists of parallel wires having an adjustable shorting bar to form a tuned circuit. Related circuitry makes it a phase nulling device, with sharp nulls occurring at each half-wave position of the shorting bar. The peak detector readout indicates the sum of all source signals when the shorting bar is in a nonnull position. A single-frequency input into the Lecher wire system will cause an output null of about 20 dB or more. Any additional frequency components will decrease this null depth. An example is shown in Fig 1 where a −20 dB spurious response is deliberately added. There isn't any question that it produces a measurable effect. Fig 2, a second example, shows the output of a singly balanced mixer with an input frequency of 144 MHz and a mixer balance of the 1.18-GHz local oscillator (LO). The mixer design enhances the upper sideband. As indicated in the figure, the upper sideband is the dominant null, but why is the base line so high? That is the 144-MHz signal source. A null from this source is not apparent due to the limited Lecher wire length. This is an example of a signal null being reduced due to a second source mixed in the output. The bottom trace is the same except the output is through an interdigital filter. Distance between nulls will indicate the signal frequency to within an accuracy of about 0.5%.

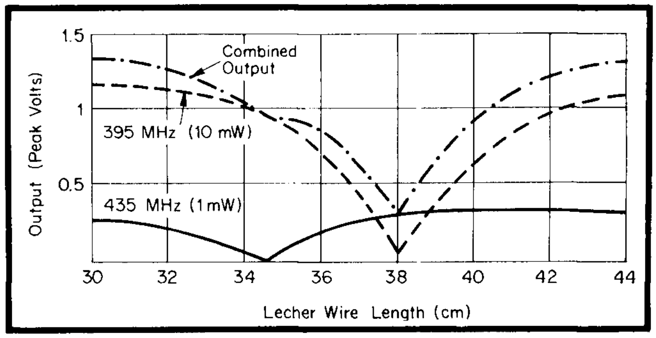


Fig 1—Lecher wire spurious response test.

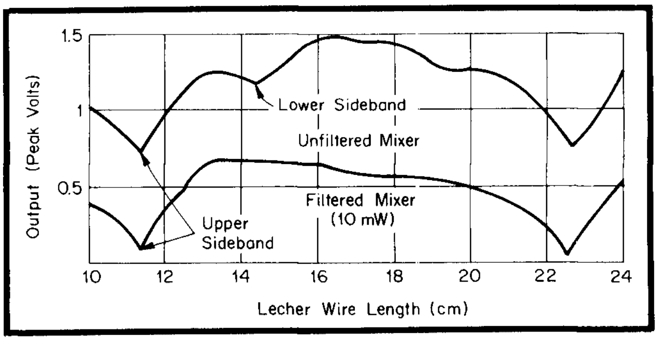


Fig 2—Lecher wire mixer response test.

Step 2 Blackbody Readout—Two 100-ohm, ½-W resistors in parallel connected across the 50-ohm cable with essentially zero lead lengths will be very close to a 50-ohm termination (SWR < 1.1:1). The problem is that connecting a readout diode across this 50 ohms introduces a capacitive reactance. Although for any particular frequency it can be tuned out with a simple parallel inductance, the question is how to confirm return to the 50-ohm termination. I do this by using 50-ohm RG-58/U as a standard. Fifty feet of this cable between the source and blackbody is a 12-dB cable attenuator at 1.3 GHz. Any load mismatch will cause an

SWR that increases the cable attenuation. Optimum match occurs when the blackbody compensation inductance is simply adjusted for maximum output. This adjustment is later optimized using the SWR device.

Step 3 SWR Device—A ¾-wave, 50-ohm stripline is inserted between the source and load. Sampling the voltage along the stripline is a direct measurement of the SWR. Although the line design is 50 ohms, its insertion will still cause minor discontinuities that will be evident by some SWR when there is a perfect match. Perfect match?—I assume a perfect match using the previously adjusted 50-ohm termination in series with the 12-dB cable attenuator (the open-ended cable alone with no termination will only have an SWR of 1.2:1). The discontinuities are nulled out using an adjustable ¼-wave stub at the SWR line termination end (SWR < 1.1:1). The SWR device was tested by inserting various lengths of RG-58/U open-ended cable. In ten-foot steps from ten to 50 feet makes SWR calibration points from 1.2:1 to 4.5:1. Comparing the results with calculated values indicated a maximum error of not more than 10%. Insertion loss of the SWR device is about 0.8 dB.

Step 4 Blackbody Trim—Check the blackbody SWR when connected directly to the SWR device. If necessary, readjust the blackbody stub for minimum SWR (< 1.1:1).

Step 5 Insertion Loss Measurement—Once having a 50-ohm blackbody with readout capability permits insertion loss measurements of cables, connectors, filters, etc. Insertion loss of nonreactive items is easy. As an example, the insertion loss of cable will be indicated by the blackbody readout simply by inserting the cable between the source and blackbody (except for connector consideration). My RG-58/U showed a loss of 0.23 dB/foot. The filter is a different consideration. It requires both a nonreactive source and termination. Again, I depend upon RG-58/U; two 20-foot sections with the single frequency source connected to one end and the blackbody/readout on the other end. With the filter connected between the cables, the 4.6-dB cable attenuation does a lot in assuring a nonreactive source and termination. My filter showed a loss of 1 dB (0.3 dB of this can be attributed to interface cabling and connectors). At the LO frequency (f − 144 MHz) the attenuation was 21 dB, and at the image frequency (f − 288 MHz) the attenuation was about 40 dB. In this case the input signal level was too weak to make an accurate measurement. Insertion loss of my old BNC connectors (some over 30 years old) resulted in minor data inconsistencies. I'm using the value of 0.1 dB/pair in evaluating equipment performance.

Step 6 Thermal Power Measurements—The previously described blackbody will measure power. However, its frequency-sensitive peak diode readout requires calibration. This is accomplished using a thermal calibration method. The method has limited dynamic range, requiring at least 0.5-W and no more than 1.5-W input. The range can be extended using cable type attenuators. The device can't be simpler. Two 100-ohm, 1/8-W resistors are connected side-by-side across a 50-ohm cable. A thermistor (reverse resistance of a 1N34A) is cemented with an instant bonding adhesive in between and on top of the resistors. The assembly is calibrated by simply applying a known dc input to the cable and recording the resulting thermistor temperature gradient. I usually use 3 minutes as the gradient time interval. The cycle is repeated by cooling the assembly with a blower to a predetermined thermistor resistance. This can be accomplished in about the same time required for the power-on calibration run. It is important to retain the same thermal conditions during the entire calibration. For that reason, the assembly is maintained in a vertical position and a foam cup is placed over the resistor/thermistor assembly during the power-on calibration period. Calibration runs are repeatable to within 0.5 dB and I have no evidence that the indicated RF output is not equal to that of the dc calibration (the amplifier efficiency is within the design goals). A typical calibration gradient curve is shown in Fig 3.

Step 7 Blackbody Calibration—Once having a calibrated amplifier output, simply exchange the thermal calibrator with the blackbody and note the output. Calibrating at 1 W will result in repeatable results to within 0.5 dB. I assume a linear diode readout except for the square law effect at the lower levels. With 1-V input, as an example, the output will be down by a factor of about 0.9, and with 0.1-V input (about 1 μW), the output will be down by a factor of about 0.6. The assembly will measure up to 1 W continuously or 2 W on an intermittent basis.

Test Assemblies

Lecher Wire System—It's hard to go wrong building this device. A gross haywire assembly will still work well. The one critical part may be the shorting bar. The system's usefulness can be limited unless the shorting bar slides easily while making good contact. My copper strip shorting bar (0.31-inch thick) uses relatively loose clearance holes for the wire and it is followed by a plastic bar so that they are held about two inches apart. The plastic bar serves to keep the shorting bar perpendicular to the wires. It's also desirable to have a plastic handle long enough so your fingers are not too close to the wires. I have marked the mounting board with a 0.3- to 1.5-GHz calibration scale, indicating frequency relative to the first null. This rough calibration is adequate for most applications. A millimeter scale is used for more accuracy. After using the device a few times you establish a feel for the null depth and waveform between nulls. Usually, a measurement lasting no more than a

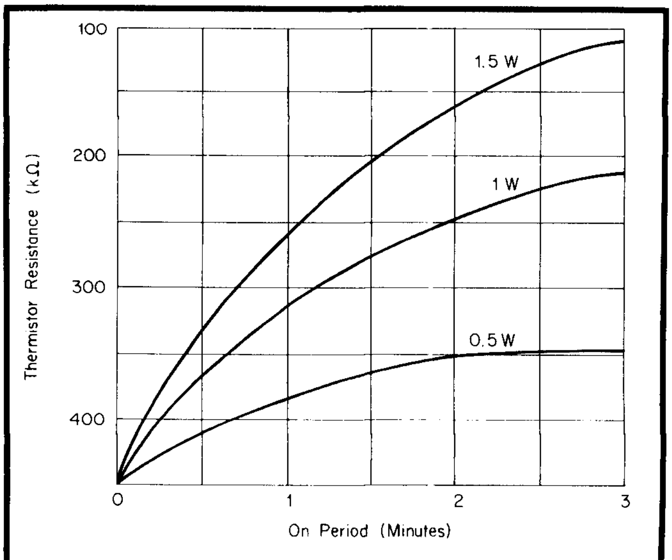


Fig 3—Thermal power measurement calibration.

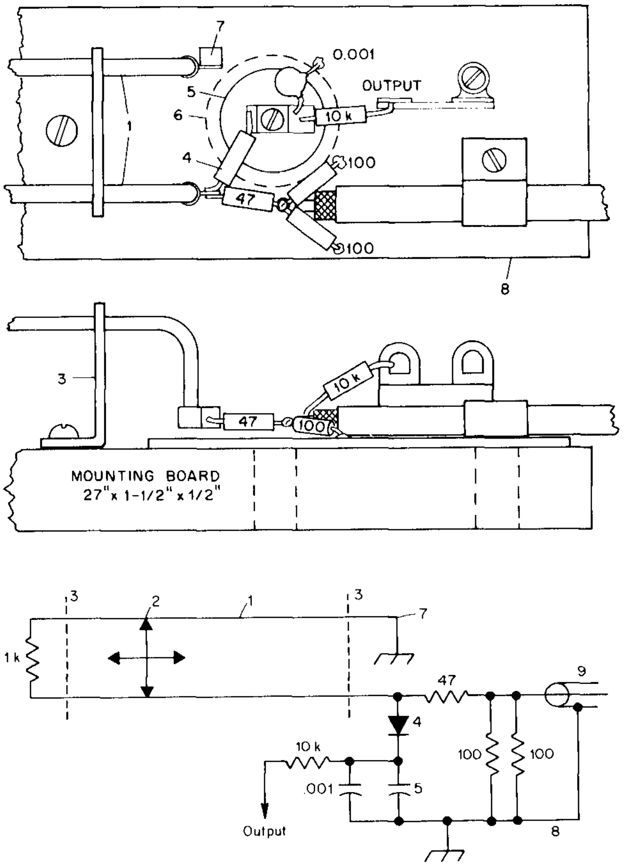


Fig 4—Schematic and layout of the Lecher wire system. All resistors are ¼ W, 5%.

1—Lecher wire line, 24 inches of no. 10 copper wires spaced ¼ inch.

2—Adjustable shorting bar. Copper, 1-1/8 × 5/16 × 0.031 inches. Clearance holes for the wires, no. 45 or 7/64-inch drill. See text for details.

3—Plastic Lecher line support insulators. There is one on each end supporting the line 5/8 inch above the mounting board. Made of polyethylene or glass-epoxy.

4—Selected 1B34A diode, >5-MΩ resistance (Radio Shack 276-1123).

5—Capacitor, 5/8-inch diameter aluminum disc fastened to the base PCB with a no. 2-56 screw. Use minimum length screw. Surface polish with 220-grit sandpaper to remove burrs. Avoid shorting of the mounting screw to the PCB foil by minimal reaming of the foil (use a large drill).

6—Capacitor dielectric is 2.7-mil polyethylene (Dow Ziploc heavy duty freezer bag).

7—Lecher wire connecting end tabs. Made from 1/8-inch-wide tin. Solder tin the strip before forming it around the wire.

8—Ground plane PCB, 2½ × 1½-inch single-sided PCB.[1]

9—Source connecting cable, RG-58/U.

[1]Available from John Meshna, Jr, Inc, PO Box 62, E Lynn, MA 01904.

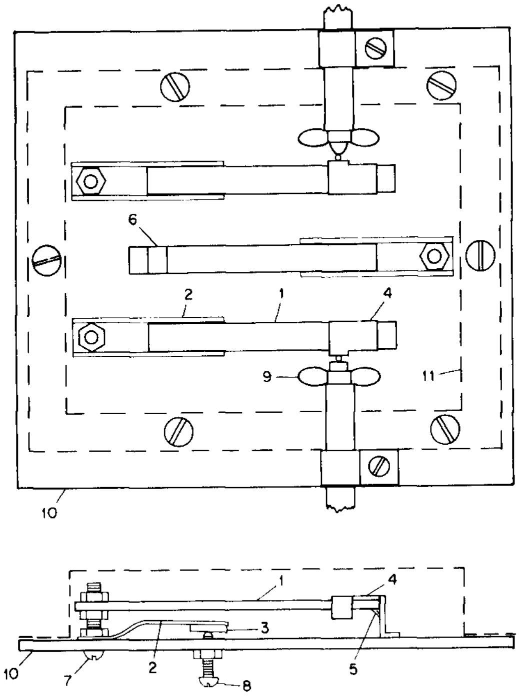


Fig 5—Layout of the interdigital filter.

1—Striplines. 2 × 3/16 × 0.059-inch double-sided glass epoxy PCB. Foil stripped from both sides ½ inch from one end. No. 2/56-clearance hole 1/8 inch from the stripped end. Lines are ½ inch between centers, and the top foils are ¼ inch above the mounting PCB foil.

2—Capacitor plates. 1 × ¼ × 0/019 inch Reynolds Aluminum. No. 2-56 clearance hole 1/8 inch from the end. Bend as shown in the detail.

3—Glass epoxy insulation ¼ × ¼ × 0.057 inch (PCB with the foil stripped off). Cement to capacitor plate as shown in the detail. (I use Elmer's Clear Household Cement.)

4—Stripline support. 11/16 × 3/16 × 0.031 inch copper with a 1/8 × 1/8 inch tab on one end (tin can be used, see text concerning performance). Bend as shown in the detail, supporting the stripline top surface ¼ inch from the mounting PCB.

5—Sweat solder the support bracket to the line top foil. Connect the support to the bottom foil with a bead of solder.

6—The center stripline support requires no cable connecting extension.

7—Stripline end support mounting hardware, ½-inch No. 2-56 screw.

8—Capacitor adjustment, No. 2-56 screw with rounded end for maintaining smooth adjustment. Screws into a nut soldered to the base PCB 3/4 inch from the end support screw. Slightly ream the top foil to prevent the adjustment screw from contacting the foil.

9—Connecting cable inner conductor is bent upward so that it can be soldered to the stripline tab. Outer braid ends are twisted together on each side and soldered to the base plate. Maintain minimum lead lengths to the base plate.

10—Double-sided glass epoxy mounting PCB, 3¼ × 3 × 0.059 inch. See Ref 1.

11—Shield made from Reynolds perforated aluminum, 1½ × 2 × 5/8 inch.

minute will tell you the story you're looking for. (Fig 4)

Interdigital Filter—Some may have a problem in finding copper for the stripline support. I tried replacing it with tin. Although the insertion loss was the same, the slightly lower stripline Q became apparent when measuring the LO rejection (f − 144 MHz). It was −17 dB rather than the copper model's −21 dB. (Fig 5)

Blackbody—The 10 kΩ resistor and one of the 0.001 μF capacitors are not indicated on the layout. These two parts are mounted on the PCB reverse side. I also have an L bracket soldered to the PCB and lying next to the cable. Taped to the cable it serves as a strain relief bracket. (Fig 6)

SWR Device—A key to good performance of this assembly is how easily you can slide the pick-up capacitor along the stripline while maintaining the capacitor plate in the proper position. As an example, make sure there are no glue bubbles along the stripline. Some of you may notice the stripline dimensions are different from those of conventional etched striplines. This is due to particular glue-down stripline edge effects (increases as the line narrows). The 50-ohm width/height factor is 1.9 (assuming e = 4.5) and the velocity factor is 0.61. (Fig 7)

Thermal Power Measurement Assembly—Remember the thermal considerations when assembling this device. Position the 100-ohm resistors to provide maximum thermal contact with the thermistor (while maintaining near-zero lead lengths). (Fig 8)

Summary

Don't let the lack of professional test equipment stop you from 1.2- to 1.3-GHz hardware activity. Actually, even when having the test equipment, reliable test data will result only when properly applying basic test procedures. Once knowing the procedures there are usually alternative tests other than the use of expensive test equipment.

If this article encourages anyone into hands-on 1.2- to 1/3 GHz activity, my effort will be well spent. I am looking forward to answering your questions. An SASE will be appreciated.

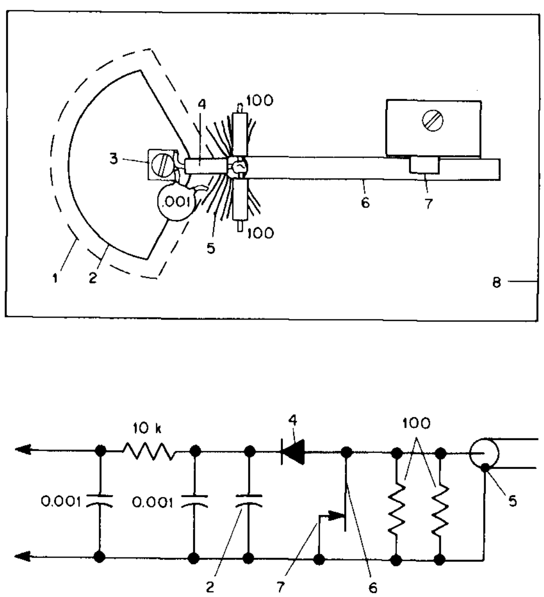


Fig 6—Schematic and layout of the blackbody/readout assembly.

Resistors are ¼ W, 5%.

1—Capacitor dielectric, 2.7-mil polyethylene from a Dow Ziploc heavy duty freezer bag.
2—Capacitor, 150-degree circular sector 5/8-inch radius made from 0.021-inch-thick Reynolds sheet aluminum. Surface polish with 220-grit sandpaper to remove burrs.
3—Feedthrough, no. 2-56 screw with a plastic insulator on the back side. Hole is slightly reamed on both sides with a large drill to prevent shorting to the foil.
4—Peak readout diode, 1N34A selected to have a reverse resistance of >5-MΩ (Radio Shack 276-1123).
5—Cable connection, RG-58/U cable feeds through a base PCB clearance hole in a perpendicular position. Outside braid is fanned out and soldered to the common PCB foil.
6—Compensating inductance, glue-down stripline 1 3/4 × 1/8 × 0.059 inch glass epoxy PCB. (I use Elmer's Clear Household Cement.)
7—Adjustable S-shaped shorting bar. It is held in position with a plastic clamp.
8—Mounting PCB, 1½ × 2 × 0.059 inch double-sided glass epoxy PCB. See Ref 1.

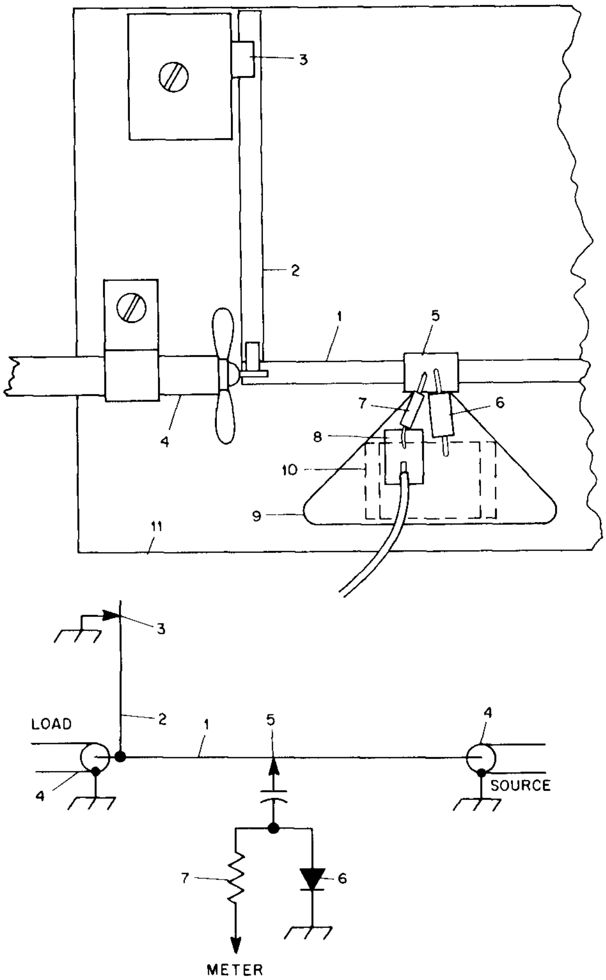


Fig 7—Schematic and layout of standing wave ratio device.

1—50-ohm, ¾-wave glue-down stripline, 5½ × 3/32 × 0.059 inch double-sided glass epoxy PCB. (Glued with Elmer's Clear Household Cement.)
2—Compensating inductance, 1-5/8 × 3/32 × 0.059 inch double-sided glass epoxy PCB. Connected to the 3/4-wave line with a short piece of desoldering braid.
3—Adjustable shorting bar held in position with a plastic clamp.
4—RG-58U cable connection, outer braid ends are twisted together on both sides and soldered to the base PCB. Keep minimum lead lengths to the PCB.
5—Stripline pick-up capacitor, 1/4 × 3/16 × 0.059 inch single-sided glass-epoxy PCB. The glass-epoxy surface is held in contact with the stripline by the related connecting components.
6—Pick-off diode, 1N34A selected to have a reverse resistance of >5 MΩ (Radio Shack 276-1123).
7—Dc pass resistor, 10 k, 1/8 W (Radio Shack 271-311).
8—Glue-down connecting pad. 1/4 × 3/16-inch PCB.
9—Tin position guide. Triangular shape 3/4 × 1/4 inch. Round the end off so that it can be easily positioned along the stripline.
10—Tin handle/shield, 3/4 × 3/8 × 1/4 inch, soldered to the position guide.
11—Base PCB, 7 × 2 1/2 × 0.059 inch double-sided glass-epoxy PCB. See Ref 1.

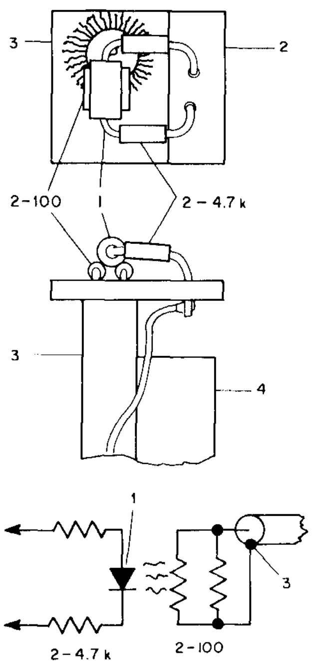


Fig 8—Schematic and layout of the thermal power measurement assembly. Resistors are 1/8 W, 5% (Radio Shack 271-311).

1—Thermistor, 1N34A (reverse resistance). It is fastened to the resistors using instant bonding adhesive (Radio Shack 64-2308).
2—Mounting PCB, 9/16 × 1/2 × 0.059 inch single-sided glass-epoxy. See Ref 1. Foil stripped from one end to make the remaining foil 1/2 × 3/8 inch.
3—Cable, 12-inch RG-58U. Cable feeds through PCB clearance hole. Outside braid is fanned out and soldered to the common PCB foil.
4—Support dowel. Cable is supported in a vertical position by being taped to a 6 × 1/4 inch wood dowel. Dowel end is inserted in a wood base plate.

HY-brid HI-Power

By Tom Pettis, KL7WE
2132 Arlington Drive
Anchorage, AK 99517

Would you like to run high power on the VHF/UHF bands without mortgaging your home? There *is* a way!

Using hybrid rings one can combine any two amplifiers having similar characteristics.

For example, a common amplifier on 144 MHz is the venerable RIW using a pair of 4CX250s. Two of these amplifiers can be connected to produce nearly 1500 W. Other amplifiers, such as the solid state "brick," can also be combined to gain a 3-dB advantage.

The total cost will amaze you! For less than $25 worth of parts (at new prices), one can produce a set of hybrid rings.

A second RIW with power supply can be purchased for less than half the price of an 8877 tube alone.

I have combined a pair of 432-MHz ARCOS amplifiers using Amperex DX-393As (Eimac 8930). The combination produces 1500 W of output power.

Theory

The concept of the frequency dependent hybrid ring is not new. It has been around for many years. For those not familiar with the concept, let me describe it in detail.

The ring consists of six (6) electrical quarter waves as shown in the diagram. A signal at port A will be equally divided between ports B and C. Zero power will appear at port D. The phase relationship at port B is −90 degrees and port C is −270 degrees. Power arriving at port D from port A via port C is −360 degrees relative to port A. Power arriving at port D from port A via port B is only −180 degrees relative to port A. The result is that at port D the signals are 180 degrees out of phase and cancel.

Power to the output ring is fed into port A and port D. Power fed into port A arriving at port D via port B is 180 degrees out of phase with that arriving via port C. The net result is that power from one amplifier is net fed into the other. Power arrives at port C in phase as a result of the 180 degree phase difference that exists in the input ring.

The advantage of this method is that the input ports of the output ring are isolated from one another, preventing meltdown of one of the amps should the other go dead.

In the event of an open at either input drive port of the output ring, one half of the drive will go to output port C and the other half will be sent to port B.

For this reason, the output ring termination must be capable of dissipating 50% of the power of either amplifier. That is to say that if you combine two amplifiers capable of producing 500 watts each, the terminating resistor must be rated at 250 watts.

Port D of the input ring must be terminated in a load capable of dissipating 50% of the drive power.

The ring itself is made of 75-ohm line. Each quarter-wave section joined to the next provides a match to 50 ohms in just the same way that it is used to transform impedances in a two-way power divider.

Construction

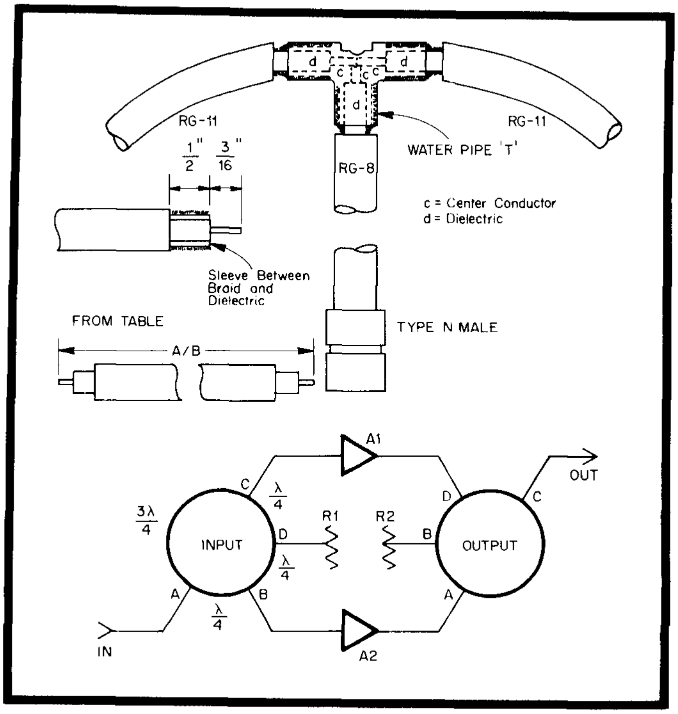
The physical length of the lines can be calculated using the dielectric constant. The lengths for each band are given in the table. (This calculation is made for a velocity factor of 0.66.)

For power levels below 100 W, such as that the input ring would be required to handle in most applications, RG-59/U coaxial cable can be used. The ring can be constructed in a metal chassis box using BNC chassis connectors. Grounding is important! The braid should be joined as close to the end of the coax sections, and hence the connectors, as possible.

A word of caution is in order. One might be tempted to try to construct the ring using coaxial T connectors and sections of coax fitted with BNC male connectors. *Don't do that!* First, it is difficult to determine the velocity factor of that combination. Second, the impedance of most T connectors I've found is unpredictable and a good match is not possible, especially at 432 MHz.

The troublesome part comes in the construction of the output ring. Here, the ring must be capable of handling up to 1500 watts.

Unless you intend to use the ring for continuous



service, you can use RG-11/U coaxial cable, provided careful construction is undertaken.

Here the process will be to build an integral ring with "pigtails" of RG-8/U for connection to the amplifiers and termination. This technique reduces losses and increases power handling capacity.

To join the ¼-wave and ¾-wave RG-11 sections of the ring to RG-8 pigtails in a practical and repeatable manner took a little thought. The problem is solved by using copper water pipe T connectors. ¼-inch fittings have about the right inside diameter. The ring can therefore be connected to amplifiers, antenna and termination without incurring excess losses. This is especially critical at 432 MHz and higher.

Begin construction by cutting three (3) lengths of RG-11 coax to dimensions A, and one (1) to dimension B. Take care to blunt cut the end so that the strands of center conductor remain together. Remove 3/16-inch of outer jacket, braid and dielectric from each end of the sections. Remove 1/2-inch outer jacket.

Select a convenient length for the RG-8 pigtails and cut four (4) equal lengths. This should be not more that 18 inches at 432 MHz. Prepare one end as described above for the RG-11. Install a type N male connector on the other end.

Cut 12 sleeves of 9/32-inch thin-wall hobby shop brass tubing 1/2-inch long. Carefully slip the tubing between the braid and the dielectric. Smooth the braid down over the tubing and solder the braid to the brass. Be sure to use a low-wattage iron for this purpose to avoid distorting the dielectric. Use of excess solder will prevent slipping the coax into the water pipe T connector.

Drill a 1/4- or 5/16-inch access hole in the top of the water pipe T connector. Be sure to deburr the inside of the hole.

Slip two RG-11 ring segments and an RG-8 pigtail into the T connector so that the three center conductors meet exactly in the middle of the connector. Use the natural curvature of the coax to help form a ring. Use some means of holding the work in place. Heat the body of the T connector allowing solder to flow inward around the circumference of the braid. You will find that the underlying brass sleeve will extend outside of the T connector providing rigidity and a means of containing the solder. Solder the three center conductors together. Make sure that you have a good connection here. Cover each joint with heat shrink tubing as you go. Repeat to complete the ring.

Testing

Each ring should be tested to ensure symmetrical power division. This is best done with low power. Power division between ports B and C should equal and result in negligible loss of power.

Next, connect the rings together without the amplifiers. The total loss through the combined setup should also be negligible. Finally, check the power at port D of each ring. The signal here must be more than 23 dB down.

If you have access to a sweep generator, you can measure the symmetry and isolation of the hybrid by inserting a signal at port A and detecting the output at port D. At the design frequency, and only the design frequency, the power at this port will be on the order of 27 dB down. Multiple notches at this port indicate lack of symmetry (measure lengths carefully). For comparison, the isolation of the input combiner made of RG-59 had better than 27-dB isolation from 400 to 440 MHz rising to 26 dB at 450 MHz. The output ring exhibited similar characteristics.

When finally connecting the amplifiers, remember that the connecting lines between the amplifiers and both the input and output rings must be the same length. This assumes that both the internal input and output circuitry of the amplifiers is the same. Some amplifiers may use a short section of coaxial cable to connect from the RF input connector to the actual grid circuit, or equivalent. Especially in home-brew amplifiers, this cable length may vary. This is not a problem. The internal lines can be made the same length, or the external lines can be made longer or shorter to compensate.

All checks having been made, you are ready for final connection.

Final Thoughts

I was reluctant to commit to the use of other than air-dielectric line for the output ring for reasons of efficiency and possible component failure. However, the temporary output ring has been in service for over 200 EME contacts during an eight-month period. Although there is some heating at the output port (C) after prolonged operation, it is not deemed serious enough to expect a failure at this junction. All other junctions are cool.

The caveat applied here is that the load (antenna) connected to the output of the ring be reasonably close to 50 ohms. SSB and CW prove no threat unless you are prone to lay a brick on the key to tune up (I suggest sending a series of dits at 40 WPM).

Good Luck!

Table 1

Band	*Length A*	*Length B*
432 MHz	4.5 inches	13.55 inches
220 MHz	8.86 inches	26.58 inches
144 MHz	13.5 inches	40.6 inches

Correspondence

On Packet Modulation Standards

I would like to respond to the letter by Charlie Solie, WB5LHV, in the June 1989 issue of *QEX*.

While I agree that using a 300-baud, 220-Hz shift modem standard simply because there are telephone modem chips available is, in the long run, unwise, I disagree with most of the rest of his letter. It should be possible to achieve reliable HF data transmission performance without excessively low transmission rates or variable baud rates. To this end, I have two suggestions for those who have time to pursue them.

First, atmospheric noise below 220 MHz is mainly due to electrical discharge effects and is characterized by short, strong noise bursts. This means that whatever your data transmission scheme, and whatever your power, if you are running any faster than about 100 baud you will have a fairly high number of bit errors. This suggests that a forward error detection and correction scheme should be used.

Second, run of the mill FSK is inefficient from a power/signal-error-rate standpoint. Some form of coherent, phase-shift scheme would be best here, with my personal favorite being MSK because it is spectrally efficient, easy to generate and, due to its constant envelope, can be amplified in a class C amplifier and retain its spectral characteristics.

With the advances in technology and communications theory that we have experienced since RTTY was young, it would be unwise for us to tie ourselves down to systems and standards that are anything but up-to-date and appropriate for the Amateur Radio Service.

I am currently working on a Master's thesis in Low-Frequency Digital Communications, and while I do not have the time or resources to pursue packet radio at this time, I am very interested. If anyone is interested in the issues that I have raised, feel free to drop me a line with questions or comments.—*Tim Wescott, N1FUW, 88 Shaker Road, Harvard, MA 01451.*

Picking Bones on the MC68701 Burner

I found Oscarson's article about the MC68701 Programming Board (May 1989 *QEX*) quite interesting, but I do have some bones to pick with him about some of the reasons given to justify his project.

It is true that S-Records created by most Motorola-oriented cross assemblers are not true "XXX.BIN" files usable by the typical "Emprom Burner" card usually available for XTs, ATs and clones. And yes, it is a time consuming proposition to generate an S19 to .BIN file converter for the PC, but why? Several have already been written and are available for next to nothing. I have two here I use (CONVERT.EXE and STOBIN.EXE) which both work quite well for the purpose. If anybody would like a copy of either or both, just send me a formatted (5.25, 360k) diskette and an sase so I can return it, and I'll be happy to forward the converters.

I have used the Stobin utility with the MC68705P3, with the attending 2716 related eprom-burner circuit as described in the 1981 Motorola Processor Data Manual, and have had good results. As far as Mr Oscarson's problem with a 2-stage transfer process (burning a 2716, then the processor ROM), I've found that I can erase both the processor and the 2716 at the same time, usually not taking more than ten minutes. It usually takes longer than that to find the bugs in the source code, reassemble the new version, etc.

I do see some merit in being able to exercise routines via RAM in the MC68701 programming board, but question the need for the rest of the circuitry. It reminds me quite a bit of a mini-emulator. I think Motorola's intentions were to try to make it as easy as possible for anyone to develop processor-based systems with their products without the need for often expensive and time consuming (to learn) support systems for development. In such I think they have succeeded.—*Ric Swendson, NY7H, 3123 West Marshall, Phoenix, AZ 85017.*