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Hydrologic and Meteorological Operations in the162-174 and 406.1-420 MHz Bands

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ABSTRACT

This report presents a detailed assessment of the hydrologic and meteorological operations in the 162-174 MHz (VHF) and 406.1-420 MHz (UHF) bands. These operations are currently supported by hydrologic and quasi-hydrologic channel assignments in these bands. There is a current need to jointly support hydrologic and nonhydrologic operations representing important national programs, and to develop solutions that alleviate spectral congestion and promote efficient spectrum utilization. This report identifies current regulations and channel usage, and analyzes the hydrologic emission characteristics to assess their bandwidth requirements and conservation alternatives. The current hydrologic channeling plans are also analyzed, and narrowband channeling options are assessed, along with the potential hydrologic service reaccommodation in current or other bands. All potential relocation and channeling options are explained and compared to illustrate their impact, tradeoffs, and compromises. The results of this study can serve to improve the spectral efficiency of hydrologic operations while remaining cost effective, and to conserve spectrum that can be made available for additional uses.

KEY WORDS

162-174 MHz Band
406.1-420 MHz Band
Hydrologic Operations
Narrowband Channeling Plans
Spectrum Conservation
Wireless Microphones

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SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the Federal Government's use of the radio frequency spectrum. NTIA's responsibilities include establishing policies concerning spectrum assignment, allocation and use, and providing the various departments and agencies with guidance to ensure that their conduct of telecommunications activities is consistent with these policies (NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management). In support of these responsibilities, NTIA has undertaken a number of spectrum resource assessments (SRAs). The objectives of these studies are to assess spectrum utilization, identify existing and/or potential compatibility problems between systems of various departments and agencies, provide recommendations for resolving any compatibility conflicts, and recommend changes to promote efficient and effective use of the radio spectrum and to improve spectrum management procedures.

This report addresses hydrologic and meteorological operations in the 162-174 MHz and 406.1-420 MHz bands. Hydrologic and meteorological stations are defined in the NTIA Manual as fixed, land, or mobile stations whose emissions are used for the automatic transmission of hydrologic or meteorological data. Hydrologic channels in the 162-174 MHz (VHF) and 406.1-420 MHz (UHF) bands can be made available to all Federal Government agencies for hydrologic operations, as well as to non-government agencies engaged in transmitting hydrologic and meteorological data in cooperation with Federal Government agencies (NTIA Manual, Section 4.3.3).

The hydrologic channels consist of 20 VHF and 8 UHF frequencies, plus an additional 1 VHF and 1 UHF frequency for quasi-hydrologic and meteorological operations (NTIA Manual, Section 4.3.3). Their availability is not limited to hydrologic operations, and may be used by all government agencies for non-hydrologic purposes when all other possibilities (except AGA(4) channels) have been exhausted, and provided that such usage does not conflict with present or probable future hydrologic operations (NTIA Manual, Section 8.3.6).

A Federal Government agency can request usage of a hydrologic channel for hydrologic or nonhydrologic operation. The Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data coordinates such requests, and provides comments to the Federal Communications Commission (FCC) and to the IRAC Frequency Assignment Subcommittee (FAS). The Hydrology Subcommittee has a Hydrologic Radio Frequency Coordination Group

(HRFCG) to review requests and provide comments via the Hydrologic Radio Frequency Coordinator who chairs the HRFCG. Coordination with the Hydrology Subcommittee is not required for the two quasi-hydrologic channels.

This joint accommodation of hydrologic and nonhydrologic operations in the hydrologic channels has been limited. Some nonhydrologic operations supporting important national programs have experienced difficulties obtaining channel assignments in the hydrologic bands, based on coordination conflicts with hydrologic operations also deemed important in the given area. These conflicts are also expected to continue and even increase in the near future, due to the growth of land-mobile usage.

On this basis, an overall study of the hydrologic plus quasi-hydrologic operations and channel utilization from a spectrum management standpoint is indicated. This task was undertaken by NTIA, and the results of the study are presented in this report, along with conclusions and recommendations to improve spectrum utilization and alleviate spectral congestion in the bands in question.

In addition to the study conducted under this NTIA task, the Interdepartment Radio Advisory Committee (IRAC) established Ad Hoc Group 205 (AH-205) to review the use of the entire 162-174 MHz band under NTIA tasking (IRAC Doc. 26315). In particular, the AH-205 tasks include investigating the potential application of narrowband or equivalent technologies to this band, determining the possible reaccommodation of existing systems to other bands for improved spectrum utilization, and reviewing the present allocation rules and channeling plans in this band towards proposing any changes deemed necessary.

The NTIA staff has actively participated in the AH-205 meetings throughout the task execution, with various letter reports contributed and study results presented by NTIA personnel attending the AH-205 sessions. The NTIA task studies have been coordinated to cooperate with the AH-205 activities, with the scope and emphasis extended to serve the AH-205 directions and concerns as needed.

OBJECTIVE

The task objective was to investigate the existing and planned usage of the hydrologic and meteorological channels in the 162-174 MHz and 406.1-420 MHz bands, to assess the potential coordination conflicts and spectrum management concerns caused by the present assignment practices and provisions, and to recommend potential solutions to improve efficient spectrum utilization and service compatibility.

APPROACH

The following approach was followed to meet the stated objectives:

- Investigate the rules and regulations pertinent to the frequency assignment and user coordination for hydrologic and meteorological channels in the 162-174 MHz and 406.1-420 MHz bands.

- Identify the agency distribution and channel usage of the hydrologic channels in the 162-174 MHz and 406.1-420 MHz bands, including hydrologic and non-hydrologic operations, as well as the potential growth impact of planned future operations.

- Analyze the station classes, emission types, modulation methods, and spectral requirements of the systems and applications supported and projected in the hydrologic channels, and assess the overall spectrum utilization and compatibility concerns accordingly.

- Identify options and alternatives for the service information transfer based on new technologies, including the potential usage of other frequency bands for service support.

- Provide recommendations for efficient spectrum utilization that supports hydrologic and nonhydrologic operations, and mitigates mutual interference potential, based on state-of-the-art technology.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The main conclusions of the study performed by the NTIA staff are listed below. A summary is appended to this section for further details and graphic illustrations of the more complex issues.

1. Hydrologic operations conducted by government and sponsored nongovernment agencies provide a valuable nationwide service, and spectrum support should be continued on a primary basis. The spectrum utilization by the hydrologic emissions should also be efficient, not only to share the limited band resources with other important nonhydrologic services, but also to benefit the hydrologic community itself in its spectrum usage.

2. A total of 28 hydrologic channels are currently allotted in the 162-174 MHz (VHF) and 406.1-420 MHz (UHF) bands for hydrologic service support under coordination by the Hydrology Subcommittee. Two other quasi-hydrologic and meteorological channels are also available without coordination required by the Hydrology Subcommittee.

3. Hydrologic channel utilization is more predominant in the VHF band than in the UHF band, both in total number of assignments and in the average number of assignments per channel.

4. Hydrologic channels predominantly support more hydrologic than nonhydrologic operations, and using predominantly fixed stations, in both bands. Nonhydrologic operations in hydrologic channels predominantly use mobile or land-mobile stations in the VHF band and fixed stations in the UHF band.

5. Hydrologic networks employ multiple hydrologic channels to support many remote data collection and backbone data/voice communication links per network. The data links support 300/1200 bps rates and the voice links support single-channel analog speech. A 1200 bps norm represents the projected trend based on increased traffic capacities and throughput demands.

6. Hydrologic emissions employ an FM carrier modulated by an audio baseband that consists of either an FSK data subcarrier (F2D emission) or single-channel analog voice (F3E emission). The FSK audio baseband typically has a 2.8 kHz lowpass occupancy for 1200

bps (2.3 kHz for 300 bps), which matches the 3 kHz speech occupancy and permits using common station equipment for data or voice communication.

7. The FSK audio baseband also permits using a multitude of conventional FSK audio modems employed for automated data dissemination and computer interfacing in the hydrologic networks. The preservation of the FSK audio baseband is important to avoid massive and expensive station modifications otherwise required if the audio modem compatibility and data/voice equipment duality disappear.

8. A 16 kHz emission bandwidth predominates in the hydrologic assignments, and represents the necessary bandwidth for the current F2D and F3E modulation specifications. Analog narrowband modulation technology can be employed to reduce the emission bandwidth while preserving the current FSK audio baseband. Digital modulation technology can also provide bandwidth reduction, but would not preserve the audio baseband.

9. Amplitude-compandored single sideband (ACSB) and narrowband frequency modulation (NBFM) represent state-of-the-art analog narrowband technology. ACSB has more bandwidth conservation potential, but also has less performance degradation immunity and would require more equipment modification. NBFM is the minimum impact solution, and suffices to render 12.5 kHz emission bandwidths compatible with narrowband channeling plans presently under consideration for the overall VHF band revision.

10. Link configuration alternatives such as satellite or meteor-burst communication do not represent cost effective options for most hydrologic operations. Their main drawbacks are the lack of real-time response compatibility with the existing facilities, along with expensive modifications and new implementations required to provide a timely response and match system specifications or operation logistics.

11. The potential reaccommodation of the hydrologic service using analog narrowband modulation technology represents the best approach to reduce spectral congestion and provide efficient spectrum utilization. Various channeling plans and band relocation options were considered, and the preferred candidate solutions were compared and assessed in the attached summary (Section 2A).

12. The potential relocation of the hydrologic service to the UHF band would require new channels allotted for this purpose, even if 12.5 kHz hydrologic channels are assumed. Conversely, the VHF band can accommodate the hydrologic service inside the current hydro blocks if 12.5 kHz hydrologic channels are employed. Moreover, there would still be a surplus of 12.5 kHz channels available inside the hydro blocks for additional uses after the hydrologic reaccommodation.

13. The narrowbanding and relocation of the hydrologic service into the VHF hydro blocks makes available at least 200 kHz of UHF bandwidth, plus a surplus of at least 100 kHz of VHF bandwidth. All this new spectrum made available can be used to support new nonhydrologic services in the VHF and UHF bands.

14. The surplus channels inside VHF hydro blocks after the hydrologic reaccommodation can be dedicated to support fixed service operations. This arrangement would provide block contiguity compatible with that currently provided to isolate the wireless microphone channels that operate inside the VHF hydro blocks on a secondary basis.

15. The current wireless microphone channeling plan is not efficient, since most microphone emissions (86%) are narrower than half the channel bandwidth allocated. All or some of the current 54 kHz microphone channels can be narrowbanded to 25 kHz, and extra microphone channels can be provided inside the VHF hydro blocks without sacrificing spectrum. The wideband microphone emissions can still be accommodated inside the VHF hydro blocks.

16. The potential relocation of the hydrologic service to other bands would not guarantee channels specifically dedicated for hydrologic operations. There are a few bands dedicated to purely fixed stations as the next compromise solution, but only the two microwave bands cited below are deemed suitable based on the current population, bandwidth span, and link reliability.

17. The 932-932.5 MHz and 941-941.5 MHz bands have been recently allocated for shared government/nongovernment use on a primary basis, and dedicated to point-to-multipoint links compatible with hydrologic operations. They are currently unpopulated, but they are expected to become rapidly congested and severely compromise the hydrologic support potential.

RECOMMENDATIONS

The following are NTIA staff recommendations based on the findings contained in this report. NTIA management will evaluate these recommendations to determine if they can or should be implemented from a policy, regulatory, or procedural viewpoint. Any action to implement these recommendations will be accomplished under separate correspondence by modifications of established rules, regulations, and procedures.

1. Hydrologic and quasi-hydrologic operations should be supported by hydrologic channels allotted in the 162-174 MHz (VHF) band for government/nongovernment use on a national primary basis.

2. A total of 28 VHF channels should be provided with a 12.5 kHz channel bandwidth. These channels should be located inside the current VHF hydro blocks, using the channeling plan shown in Figure 2-2, Option A, as next described.

3. The 20 current VHF hydrologic frequencies inside the hydro blocks should remain allocated to hydrologic operations, but their current 25 kHz channel bandwidths should be reduced to 12.5 kHz. The 16 current VHF interstitial frequencies inside the hydro blocks should be allocated to form new channels with 12.5 kHz bandwidths, and used to support hydrologic and nonhydrologic operations as follows.

4. The eight interstitial frequencies inside the first and second VHF hydro blocks should be allocated to hydrologic operations, along with the current 20 hydrologic frequencies. The eight interstitial frequencies inside the third and fourth hydro blocks should be allocated to All Government Agencies (AGA) for fixed service operations.

5. Hydrologic operations in the 406.1-420 MHz (UHF) band should be relocated to the 12.5 kHz hydrologic channels created inside the VHF hydro blocks. A total of 28 VHF hydrologic channels would be available as previously described.

6. Assignments in the current VHF or UHF hydrologic channels, or in their adjacent interstitial channels, should be grandfathered in the 25 kHz to 12.5 kHz narrowband transition and channel relocation process. New assignments in the current VHF hydrologic or interstitial channels inside the hydro blocks should be required to satisfy the 12.5 kHz channel bandwidths after a set transition date that should coincide with the UHF hydrologic relocation. This transition date should also conform with any date established for the implementation of a 12.5 kHz channeling plan for the entire VHF band, or for any portion of this band that includes the current VHF hydro blocks. The transition dates suggested are January 1, 1995, for all new equipment and January 1, 2005, for all equipment to operate in 12.5 kHz VHF channel bandwidths.

7. The Hydrologic Subcommittee should maintain the responsibility for coordinating hydrologic channel use requests to the Frequency Assignment Subcommittee, before and after the narrowband transition and channel relocation process.

8. The current VHF wireless microphone channeling plan should be modified to provide 25 kHz channel bandwidths as shown in Figure 2-3, Option A. Wireless microphone

operations with emission bandwidths not exceeding 54 kHz should still be supported, and assigned to any of the channel frequencies in the new channeling plan.

9. The NTIA Manual should be modified as follows if the new hydrologic channeling plan and band reaccommodation proposed in this section are adopted.

(a) The hydrologic channel frequencies (MHz) listed in Section 4.1.3 Footnote US13 and in Section 4.3.3 should be

169.4250	170.2250	171.0250	171.8250
169.4375	170.2375	171.0500	171.8500
169.4500	170.2500	171.0750	171.8750
169.4625	170.2625	171.1000	171.9000
169.4750	170.2750	171.1250	171.9250
169.4875	170.2875		
169.5000	170.3000		
169.5125	170.3125		
169.5250	170.3250		

(b) The meteorological channel frequencies (MHz) listed in Section 4.3.3 should be 171.175 only.

(c) The 406.1-420 MHz band should be omitted in the title of Section 8.3.6.

10. The NTIA Manual should be modified as follows if the new wireless microphone channeling plan proposed in this section is adopted.

The wireless microphone channel frequencies (MHz) listed in Section 4.1.3 Footnote US300 and in Section 4.3.2 should be

169.445	170.245	171.045	171.845
169.475	170.275	171.075	171.875
169.505	170.305	171.105	171.905

A similar modification should be implemented in the FCC/CFR Section 90.265 (Federal Communications Commission, Code of Federal Regulations).

SECTION 2A

SUMMARY

The assessment of current hydrologic and meteorological operations from a spectrum management standpoint requires awareness of many complex and interrelated issues. This summary provides a proper perspective of the main issues and solution compromises involved, and compares various narrowband channeling plans and service recommendation options. In particular, a concise assessment table is presented to guide logical management decisions towards an efficient spectrum utilization that alleviates hydrologic/nonhydrologic user congestion and mitigates mutual interference potential.

HYDROLOGIC SPECTRUM UTILIZATION

Hydrologic operations conducted by government and sponsored nongovernment agencies provide a valuable nationwide service, and spectrum support should be provided on a primary basis. The spectrum utilization by the hydrologic emissions should also be efficient, not only to share the limited band resources with other important nonhydrologic services, but also to benefit the hydrologic community itself in its spectrum usage.

The hydrologic operations are mainly supported by 21 VHF and 9 UHF hydrologic channels, including one quasi-hydrologic channel in each band. The VHF usage is considerably more than the UHF usage, with 2745 VHF and 362 UHF current hydrologic assignments in the hydrologic channels. There are also some hydrologic assignments in nonhydrologic channels in both bands, representing 12% (VHF) and 4% (UHF) of the total hydrologic operations.

The hydrologic channels predominantly support more hydrologic than nonhydrologic assignments (88% VHF, 96% UHF), and with predominantly fixed hydrologic stations (91% VHF, 99% UHF). Nonhydrologic assignments in hydrologic channels predominantly use mobile or land-mobile stations in the VHF band, and fixed stations in the UHF band.

HYDROLOGIC EMISSIONS AND BANDWIDTH CONSERVATION

A 25 kHz hydrologic channel bandwidth is provided in both bands. A 16 kHz assigned bandwidth predominantly represents the hydrologic operations, as well as the nonhydrologic operations in hydrologic channels. This bandwidth usually supports two types of hydrologic emissions (F2D, F3E) regularly employed for remote data collection and backbone data/voice communications in the hydrologic operations.

The F2D (data) emissions consist of an FSK data subcarrier modulating an FM carrier, and the F3E (voice) emissions consist of a single speech channel also modulating an FM carrier. The FSK audio baseband typically has a 2.3/2.8 kHz lowpass bandwidth for 300/1200 bps data rates, which matches the 3 kHz speech baseband occupancy to permit using common station equipment for data and voice communications. The 1200 bps rate should be assumed to set current standards, as increased throughput capabilities are being demanded to meet traffic requirements.

The FSK audio subcarrier (audio tones) also supports a multitude of conventional FSK modems, which are employed by the hydrologic networks and community facilities to provide automated computer interfacing, data dissemination, and RS-232 standards conversion. The use of direct-carrier digital modulation technology for the data emissions would conserve bandwidth, but at a prohibitive cost in the massive amount of modem replacement and new dedicated station equipment (transmitters, repeaters, receivers) that would be needed.

The hydrologic emission bandwidth can be effectively reduced for spectrum conservation by using narrowband analog modulation technology, such as amplitude compandored single sideband (ACSB) or narrowband frequency modulation (NBFM), while preserving the existing data/voice audio basebands in the hydrologic emissions. In particular, NBFM technology represents a minimum impact solution in equipment modification and performance compromise, and it suffices to render less than 12.5 kHz emission bandwidths compatible with narrowband channeling plans.

WIRELESS MICROPHONE OPERATIONS

Wireless microphone wideband (54 kHz) channels are also provided in the VHF band, and support nonhydrologic government/nongovernment operations on an unprotected secondary basis. These channels are currently allotted as pairs inside blocks formed by contiguous VHF hydrologic channels, which isolates the wireless microphone emissions and mitigates the mutual interference potential between them and other services in the band.

The wireless microphone emissions are predominantly much narrower than their 54 kHz channel allocation. Only 14% of the microphone assignments have emission bandwidths of 30 kHz or more, whereas 86% have 20 kHz or less emission bandwidth, so that the majority occupies less than half the channel bandwidth. The wideband microphones are also equally distributed over all their channels, which is not efficient spectrum utilization; i.e., all wideband channels are currently supporting predominantly narrower microphone emissions.

HYDROLOGIC NARROWBAND CHANNELING PLANS AND REACCOMMODATION ASSESSMENT

The current UHF hydrologic channeling plan is inefficient, because only three of the nine channels are contiguous as shown in Figure 2-1. The nonhydrologic gaps result in only two interstitial channels reliable for hydrologic support, by having adjacent hydrologic channels on both sides. The other interstitial channels have adjacent mobile and land-mobile operations on one side, which could interfere with hydrologic interstitial operations.

A 12.5 kHz UHF hydrologic channeling plan can provide only 11 narrowband channels when using the current hydrologic and their reliable interstitial frequencies, or only 18 narrowband channels when splitting the current hydrologic channels, as shown in Figure 2-1. If the current 25 kHz UHF gaps between neighboring hydrologic channels were dedicated to hydrologic operations, the number of 25 kHz channels increases from 9 to 13, and the number of 12.5 kHz channels increases from 11 to 23 or from 18 to 26, as shown in Figure 2-1.

Conversely, the current VHF hydrologic channeling plan is efficient, as 20 of the 21 channels available form four blocks of five contiguous channels each. This renders 16 interstitial channels reliable for hydrologic support, since they have adjacent hydrologic channels on both sides. The channel contiguity also provides a 125 kHz spectral umbrella for two 54 kHz wireless microphone channels inside each hydro block.

A 12.5 kHz VHF hydrologic channeling plan can be provided by narrowbanding the VHF hydrologic channels, and using their interstitial frequencies to create the other channels as shown in Figure 2-2, Option A. An alternative approach is to split the VHF hydrologic channels into narrowband pairs as shown in Figure 2-2 Option B, which would require a 6.25 kHz center frequency shift along with narrowbanding.

These VHF narrowband plans provide 36 (Option A) or 40 (Option B) total 12.5 kHz channels inside the hydro blocks. These new channels could support the current VHF hydrologic channels (narrowbanded) and the current UHF hydrologic channels (relocated and narrowbanded), and still leave a surplus of 12 kHz channels for nonhydrological support inside the hydro blocks. These extra channels could be dedicated to fixed service operations, so as to help maintain the block isolation currently provided for the VHF wireless microphone channels.

The VHF spectrum utilization by wireless microphones can itself be improved by creating narrowband channels from the current 54 kHz channels as shown in Figure 2-3. A frequency stability of about 15 ppm (± 2.5 kHz drift) or 20 ppm (± 3.5 kHz drift) would suffice for the 25 kHz or 27 kHz channel bandwidths, respectively.

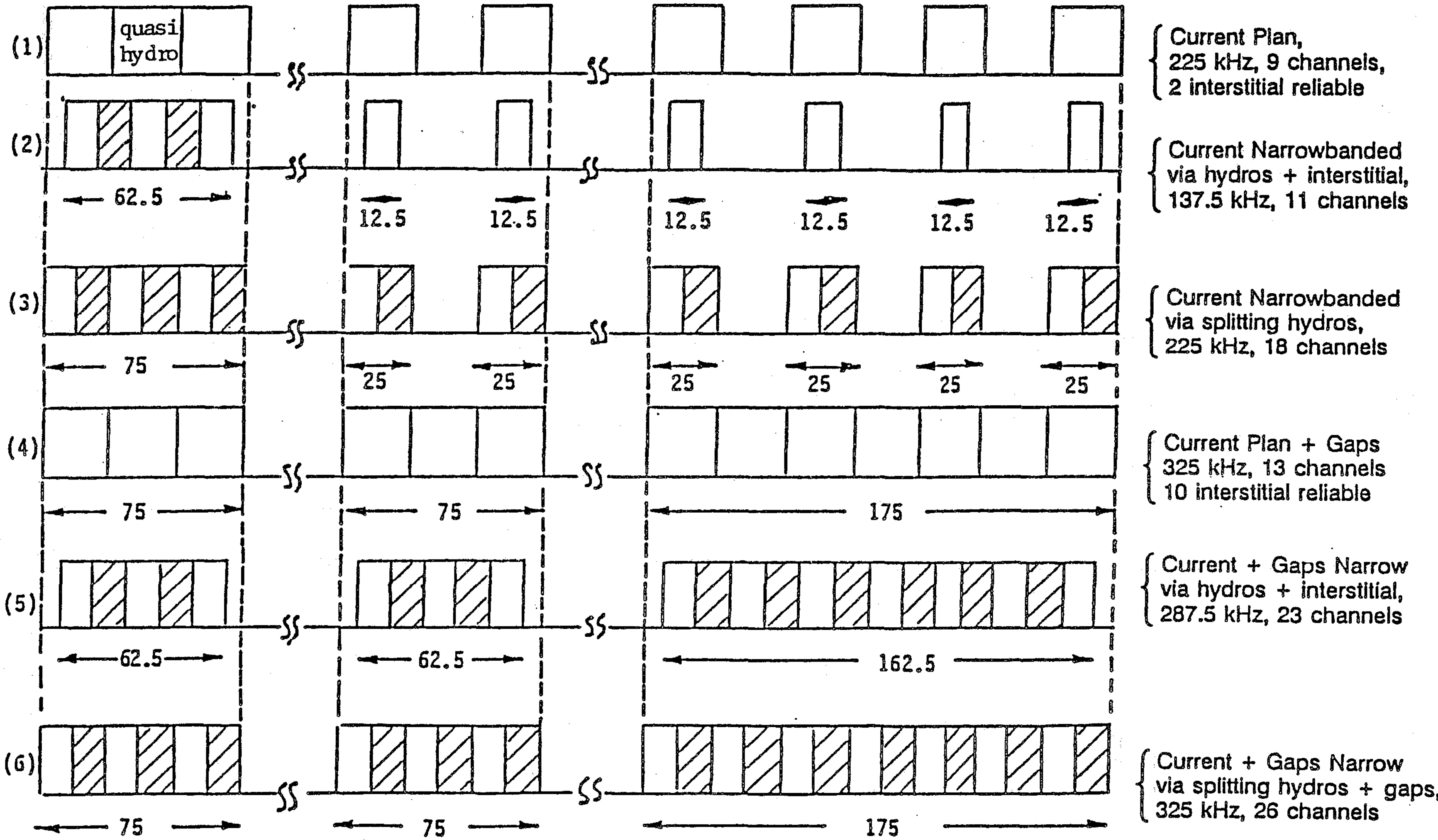
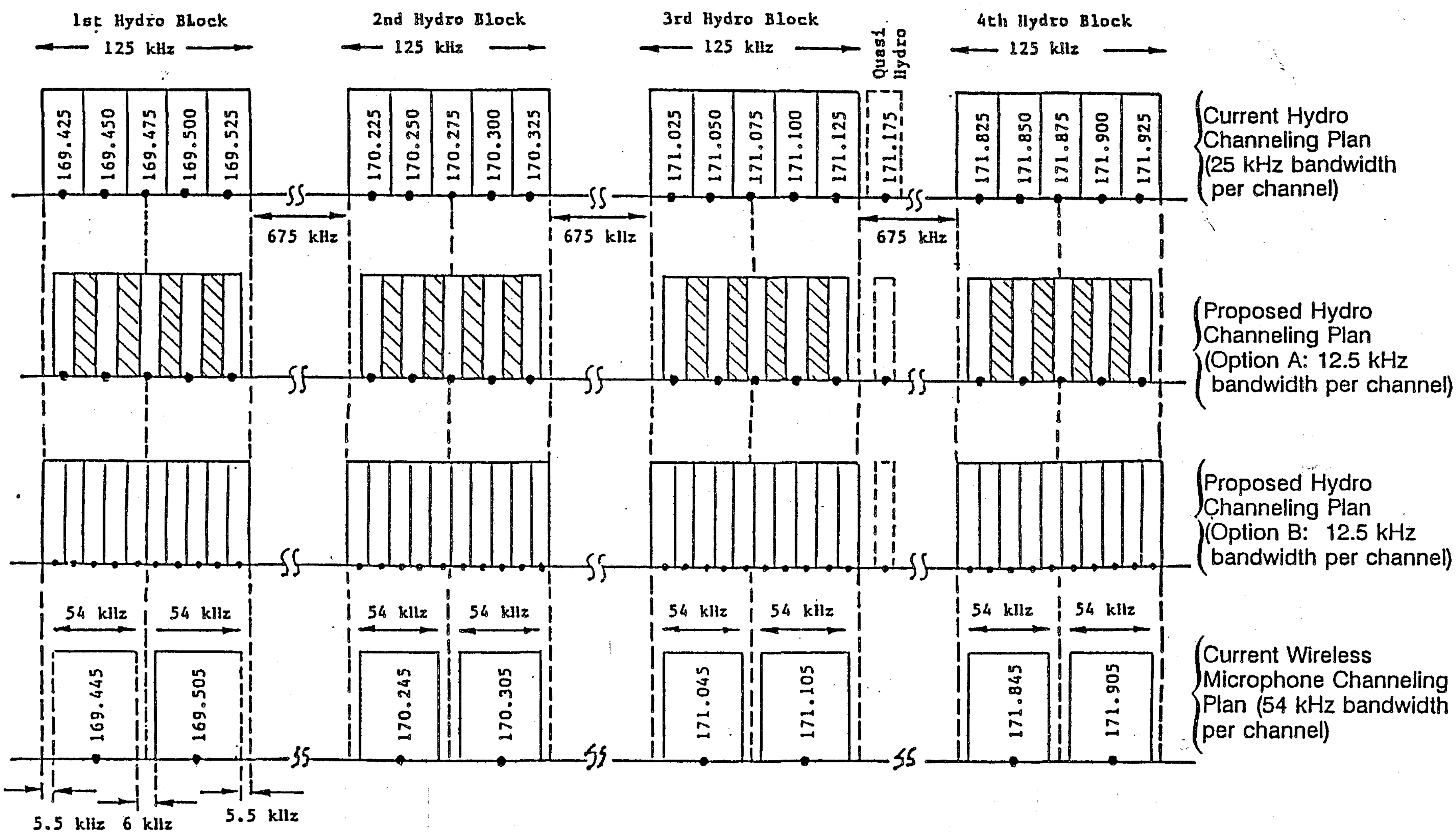


Figure 2-1. UHF Hydrologic Channeling Plan Options.



Note: Proposed Hydrologic Channeling Plan Options:

Option A (12.5 kHz bandwidth): case of hydrologic and interstitial frequencies preserved.

Option B (12.5 kHz bandwidth): case of hydrologic channels split with hydrologic frequencies shifted, and interstitial frequencies abolished.

Figure 2-2. VHF Hydrologic Current and Narrowband Channeling Plans.

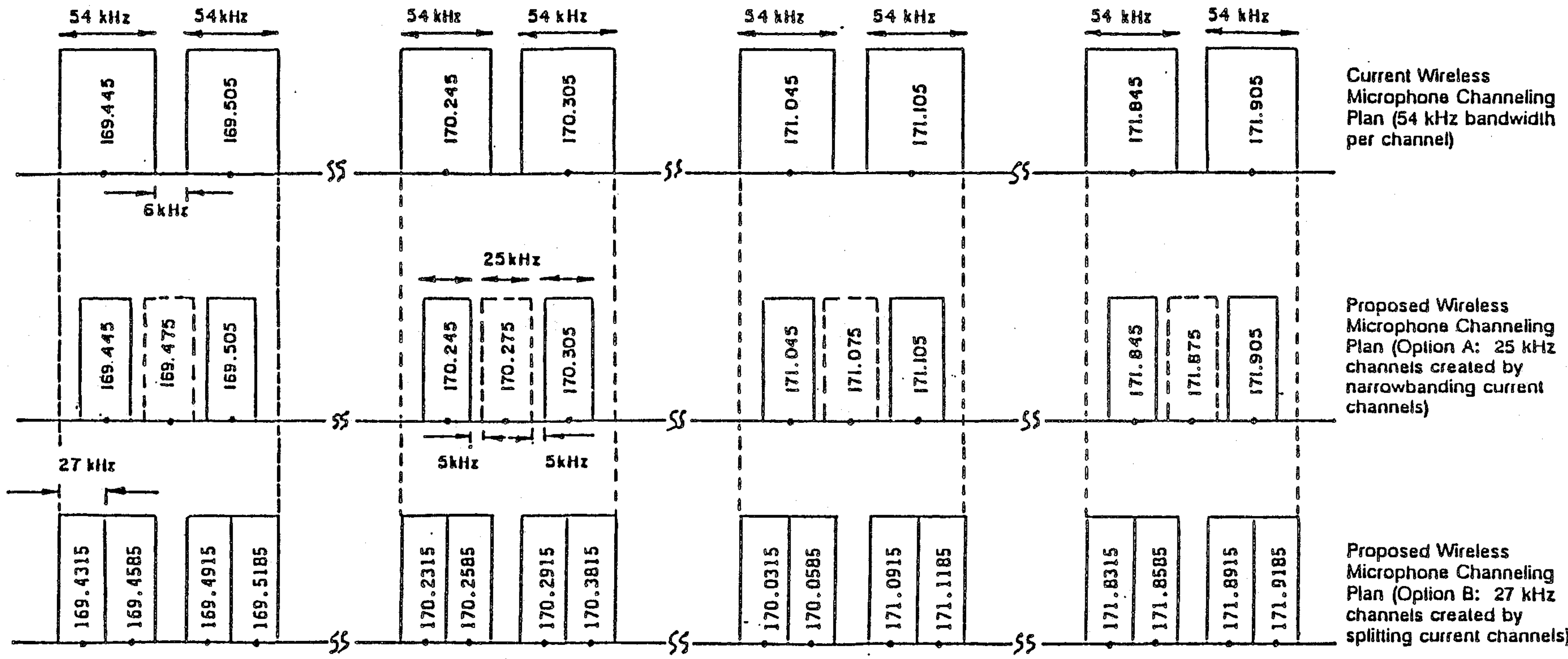


Figure 2-3. VHF Wireless Microphone Current and Narrowband Channeling Plans.

Wideband microphone assignments can still be allowed by letting them span more than the narrowband channel bandwidth. Alternatively, the first block of Figure 2-3 could be preserved in its current 54 kHz plan, while the remaining blocks are narrowbanded as per options A or B. Bandwidth-selective assignments would be required to pool the wideband microphone assignments into the first block when preserving the two wideband channels.

The potential joint relocation of the VHF and UHF hydrologic service to another band has two microwave bands (932-932.5 MHz, and 941-941.5 MHz) as main candidates. These bands have been recently allocated to only the Fixed Service for shared government and nongovernment use, and specifically dedicated to single-channel, point-to-multipoint applications, which is compatible with the hydrologic operations.

These two microwave bands can jointly accommodate all the VHF and UHF hydrologic channels with 25 kHz channel bandwidths, or individually with 12.5 kHz channel bandwidths. FM and NBFM equipment is commercially available in these bands to support the F2D/F3E emissions with either 25 kHz or 12.5 kHz channel bandwidths.

These microwave bands are currently unpopulated, but are expected to become congested very rapidly with diverse applications. Hydrologic channels are not guaranteed in these bands, unless new regulations are made, and the hydrologic service support could be compromised.

An assessment of the various hydrologic service reaccommodation options and channeling plans is shown in TABLE 2-1, to illustrate their relative advantages and disadvantages, and provide a logical perspective of the solution compromises involved.

TABLE 2-1
(page 1 of 3)

HYDROLOGIC SERVICE REACCOMMODATION ASSESSMENT

OPTIONS	ADVANTAGES	DISADVANTAGES	REMARKS
(A) VHF relocation to UHF band	1. Opens VHF spectrum (525 kHz liberated) 2. UHF hydro operations are experienced	1. New UHF hydro spectrum must be created. Nonhydro operations to be grandfathered would be a potential interference source to new hydro channels until phased out. 2. VHF wireless microphone channels lose hydro block isolation.	1. The current 21 VHF and 9 UHF hydro channels have 25 kHz bandwidths, and occupy a 525 kHz VHF and 225 kHz UHF total span. 2. These channels currently support 2745 VHF and 362 UHF hydro assignments, so that the channel usage is lower at UHF than VHF on the average.
(A.1) Case of 25 kHz channels	3. UHF equipment commercially available	3. 525 kHz extra hydro spectrum needed for 30-channel support, 300 kHz extra still needed for 21-channel support, (9 VHF channels absorbed into 9 UHF channels). 4. Only 13 total UHF channels can be supported by allocating the current 25 kHz nonhydro gaps.	3. The current UHF hydro plan is inefficient, since the hydro blocks have few and usually noncontiguous channels, with only 2 reliable interstitial hydro channels.
(A.2) Case of 12.5 kHz channels	3. Only 37.5 kHz extra spectrum needed for 21-channel support 4. 23-channel or 26-channel support can be provided by allocating the 25 kHz nonhydro gaps. 5. 23-channel support provided without shifting current hydrologic or interstitial center frequencies.	3. 150 kHz extra hydro spectrum needed for 30-channel support, and allocating the 25 kHz nonhydro gaps would not suffice (see Figure 2-1). 4. 26-channel support provided via split channels requiring 6.25 kHz shift in current hydrologic and interstitial center frequencies. 5. UHF equipment not commercially available.	4. The current 25 kHz nonhydro gaps in the UHF hydro blocks could be allocated for hydro support to have contiguous channels and gain some hydro bandwidth.

TABLE 2-1
(page 2 of 3)

OPTIONS	ADVANTAGES	DISADVANTAGES	REMARKS
(B) UHF relocation to VHF band	1. Opens UHF spectrum (225 kHz liberated) 2. VHF hydro operations are experienced. 3. Minimum impact relocation since VHF usage predominates.		1. The current VHF hydro plan is efficient, since the hydro blocks have contiguous channels that render 16 reliable interstitial hydro channels. 2. The contiguous channels and interstitial reliability facilitate the creation of 36 narrowband (12.5 kHz) channels inside the hydro blocks, and without any center frequency shifts. 3. Alternatively, 40 protected channels can be created inside the hydrologic block by splitting current channels, but requiring 6.25 kHz center frequency shifts. 4. The current distribution assignments in the VHF wireless microphone channels is not efficient. All eight channels are wideband and all support a minority of wideband microphones, along with the majority of narrower microphones that occupy less than half the channel bandwidth. 5. Most wireless microphones emissions are much narrower than the hydro block isolation span provided.
(B.1) Case of 25 kHz channels	4. VHF equipment commercially available. 5. VHF wireless microphone channels keep hydro block isolation. 6. Current 21 hydro and 16 reliable interstitial channels may suffice to support entire UHF hydro service.	1. Incompatible with 12.5 kHz channeling trend for entire band. 2. 225 kHz extra hydro spectrum needed for 30-channel support (severely augments band congestion). 3. Absorption of UHF hydros by current VHF hydros does not help relieve VHF band congestion.	
(B.2) Case of 12.5 kHz channels	4. Compatible with 12.5 kHz channeling trend for entire band. 5. 36-channel or 40-channel support can be provided by narrowbanding current hydro blocks. 6. Opens VHF spectrum. All 30 hydro channels can be accommodated inside current VHF hydro blocks, and still leave a surplus of 75 kHz (Option A) or 125 kHz (Option B) total inside blocks, plus 25 kHz outside in quasi-hydro slot.	1. VHF NBFM equipment commercially available in Europe but not U.S. (ACSB available in U.S.) 2. VHF wireless microphone channels could lose their block isolation depending on surplus dedication (e.g., surplus used for Mobile or Land-Mobile Services).	

(Continues on next page)

TABLE 2-1
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OPTIONS	ADVANTAGES	DISADVANTAGES	REMARKS
(B.2) Case of 12.5 kHz channels (continued)	7. Surplus inside new narrowband blocks is open spectrum (besides UHF hydros) to support nonhydro services. Wireless microphone channels can keep most (Option A) or all (Option B) block isolation if surplus dedicated to Fixed Service (point-to-multipoint). 8. Fixed Service relocation to surplus channels is compatible with 12.5 kHz channeling plan being developed for entire band.	3. Surplus dedication to Fixed Service would require relocation within VHF band itself to gain spectrum for Mobile and Land-Mobile Services	6. Wireless microphone channels can be made efficient by narrowbanding most or all 54 kHz channels. Three 25 kHz or four 27 kHz narrowband channels can be created inside a hydro block.
(C) VHF and UHF relocation to other band(s)	1. Opens VHF and UHF spectrum (750 kHz total liberated) 2. Microwave bands currently available for purely Fixed Service support, and with enough bandwidth span to accommodate all 30 hydro channels with 25 kHz or 12.5 kHz plans. 3. Two microwave subbands with 600 kHz span each (932-932.5 MHz 941-941.5 MHz) recently opened for point-to-multipoint fixed support (hydro operations compatible). 4. HDFM equipment commercially available to support these microwave bands with either 25 kHz or 12.5 kHz channel bandwidths. Current or narrow-band F2D/F3E hydro emissions can be supported while preserving data/voice audio basebands.	1. No hydro microwave operation experience. 2. Maximum impact in equipment replacement amount. 3. Microwave bands are for shared government/nongovernment support No specific hydro channel dedication unless new regulations are made. 4. Microwave bands are now virtually unpopulated, but also expected to get filled very rapidly with diverse applications. Hydrologic service support can be compromised.	1. The only other purely Fixed Service bands are below 20 MHz. Most are either limited in bandwidth span, or will fit hydro span tightly.

SECTION 3

RULES AND REGULATIONS

NATIONAL FREQUENCY ALLOCATIONS

The current version of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management (see Reference 1) has the National Frequency Allocations shown in TABLES 3-1 (VHF) and 3-2 (UHF) for the 162-174 MHz band (VHF) and 406.1-420 MHz band (UHF), respectively. The bands support the Fixed, Mobile, and Radio Astronomy services for government and/or nongovernment operations on a primary basis, as well as Land Mobile nongovernment operations on a secondary basis.

There are also many footnote regulations pertaining to specific national government (G, US), national nongovernment (NG, US) or international (#) operations in certain frequencies or band portions, as summarized in TABLES 3-3 (VHF) and 3-4 (UHF). These tables also include the footnotes to the Channeling Plan (FCP) for the VHF and UHF bands pertaining to the hydrologic/meteorological and quasi-hydrologic channels.

There are 20 VHF and 8 UHF channels allotted to hydrologic operations, and 1 VHF and 1 UHF channel allotted to meteorological and quasi-hydrological operations, as listed in TABLE 3-5 (NTIA Manual, Section 4.3.3). There is no more specific definition of these operations, other than stating that their station emissions are used for the automatic transmission of hydrologic and/or meteorological data (NTIA Manual, Section 6.1.1).

The hydrologic channels are mainly to be used for hydrologic operations by the (Federal) Government agencies, or by nongovernment agencies engaged in hydrologic operations in cooperation with the government agencies (NTIA Manual, Section 4.3.4). Nongovernment operations are identified as fixed hydrologic/meteorological stations causing no interference to government stations (NTIA Manual, Table of Frequency Allocations, US13 Footnote). The nongovernment usage presently represents about one-third of the hydrologic channel operations.

The hydrologic channels can also be used for nonhydrologic operations by the government agencies, usually after other possibilities are exhausted, and provided that such usage does not conflict with existing or projected hydrologic operations (NTIA Manual, Section 8.4.6). There are presently government nonhydrologic operations in some hydrologic channels, as well as government/nongovernment hydrologic operations in channels other than those reserved for hydrologic operations, as shown later in this report.

TABLE 3-1

NATIONAL FREQUENCY ALLOCATION FOR THE 162-174 MHz BAND

Band MHz 1	*National Provisions* 2	*Government Allocation* 3	*Non-Government Allocation* 4	*Remarks* 5
162.0125-173.2	US8 US11 US13 US216 US223 US300 613	FIXED MOBILE G5		The Channeling Plan for assignments in this Band is shown in Section 4.3.7 of the NTIA Manual.
173.2-173.4			FIXED Land Mobile NG124	Industrial Public safety
173.4-174		FIXED MOBILE G5		The Channeling Plan for assignments in this Band is shown in Section 4.3.7 of the NTIA Manual.

TABLE 3-2

NATIONAL FREQUENCY ALLOCATION FOR THE 406.1-420 MHz BAND

Band MHz 1	*National Provisions* 2	*Government Allocation* 3	*Non-Government Allocation* 4	*Remarks* 5
406-406.1	649	MOBILE-SATELLITE (Earth-to-space)	MOBILE-SATELLITE (Earth-to-space)	Emergency Position-Indicating radiobeacon (EPIRB).
406.1-410	US13 US74 US117	FIXED MOBILE RADIO ASTRONOMY G5 G6	RADIO ASTRONOMY	The Channeling Plan for assignments in these bands is shown in Section 4.3.9 of the NTIA Manual.
410-420	US13	FIXED MOBILE G5		

TABLE 3-3

VHF BAND ALLOCATION SUMMARY (162-174 MHz)

162.0125-173.2 MHz:	Fixed and Mobile Service (Government, Primary)
G5:	non-military agencies
US8:	nine channels for nonfederal forest firefighting agencies (fixed, land, and land mobile stations), two of them also for nonfederal conservation agencies (mobile relay stations)
US11:	two channels for nongovernment remote pickup broadcast (base and land mobile stations) and nongovernment public safety radio (fixed, base, and land mobile stations)
US13:	twenty hydrologic/meteorological channels can be authorized to nongovernment fixed stations associated with government operations, provided no interference is caused to government stations.
US216:	a 25 kHz subband around 163.25 MHz for government/nongovernment medical radio communications
US223:	one maritime mobile channel (162.025 MHz) for US/Canada border transmissions
US300:	eight channels for government/nongovernment wireless microphone operations on a secondary basis
613:	maritime mobile priority channels below 162.05 MHz
FCP8:	Primarily for hydrologic use. Shared with nongovernment under note US13.
171.175 MHz:	Fixed and Mobile Service (Government, Primary)
FCP9:	Primarily for meteorological and quasi-hydrologic operations outside the purview of the Hydrology Subcommittee.
173.2-173.4 MHz:	Fixed Service (Nongovernment, Primary) Land Mobile Service (Nongovernment, Secondary)
NG124:	Low-power police radio transmitter on a secondary, noninterference, basis
173.4-174 MHz:	Fixed and Mobile Service (Government, Primary)
G5:	non-military agencies

TABLE 3-4

UHF BAND ALLOCATION SUMMARY (406.1-420 MHz)

406.1-410 MHz:	Fixed and Mobile Service (Government, Primary), Radio Astronomy Service (Government/Nongovernment, Primary)
G5:	nonmilitary agencies
G6:	military tactical fixed and mobile operations for meteorological aids or radio astronomy on a secondary basis
US13:	eight hydrologic/meteorological channels can be authorized to nongovernment fixed stations associated with government operations, provided no interference is caused to government stations.
US74:	radio astronomy protection from extraband radiation only if the latter exceeds its technical standards for emission levels
US117:	7 kW/kHz limit after November 30, 1970; special coordination requirements for certain specific Radio/Solar Observatory areas; nongovernment usage restricted to radio astronomy and hydrological operations
FCP8:	Primarily for hydrologic use. Shared with nongovernment under note US13.
406.150 MHz:	Fixed and Mobile Service (Government, Primary), Radio Astronomy Service (Government/Nongovernment, Primary)
FCP9:	Primarily for meteorological and quasi-hydrologic operations outside the purview of the Hydrology Subcommittee
410-420 MHz:	Fixed and Mobile Service (Government, Primary)
G5:	see above
US13:	see above

TABLE 3-5

HYDROLOGIC AND METEOROLOGICAL CHANNEL FREQUENCIES (MHz)

VHF HYDROLOGIC CHANNELS

• • • •	• • • •
169.425	171.025
169.450	171.050
169.475	171.075
169.500	171.100
169.525	171.125
• • • •	• • • •
170.225	171.825
170.250	171.850
170.275	171.875
170.300	171.900
170.325	171.925
• • • •	• • • •

UHF HYDROLOGIC CHANNELS

• • • •	• • • •
406.125	412.625
406.175	412.675
• • • •	• • • •
409.675	412.725
409.725	412.775
• • • •	• • • •

VHF METEOROLOGICAL AND QUASI-HYDROLOGIC CHANNEL

171.175

UHF METEOROLOGICAL AND QUASI-HYDROLOGIC CHANNEL

406.150

TABLE 3-6

VHF WIRELESS MICROPHONE CHANNEL FREQUENCIES (MHz)

• • • •	• • • •
169.445	171.045
169.505	171.105
• • • •	• • • •
170.245	171.845
170.305	171.905
• • • •	• • • •

There are also eight VHF channels allotted to wireless microphone operations on an unprotected, noninterfering, secondary basis relative to other authorized services (NTIA Manual, Section 4.3.2). These wireless microphone channels are centered offset by ± 5 kHz relative to some of the VHF hydrologic channels, as listed in TABLE 3-6. There are no UHF channels allotted to wireless microphone operations.

The wireless microphone operations are also addressed in the Federal Communications Commission-Code of Federal Regulations (FCC-CFR), Part 90.17. The 169-172 MHz band is allocated to the Mobile Service and, by footnote 27, some frequencies in this band are assigned for low power wireless microphones. Part 90.265 of the FCC-CFR identifies the wireless microphone frequencies and operational specifications such as emission bandwidth, output power, oscillator drift, interference, etc., which are similar to those in the NTIA Manual, Section 4.3.2.

Wireless microphone operations are also authorized by the FCC-CFR, Part 74.801-802, as low power auxiliary stations that can transmit over distances of approximately 100 meters. There are various frequency bands available for these wireless microphone operations, ranging from 26.1-26.48 MHz at the low end to 944.0-952.0 MHz at the high end.

There are two types of wireless microphone applications. The operations supported by the 169-172 MHz band (Part 90.265) represent the general purpose application (e.g., churches, lectures, concerts, sports, fast food, banks, etc.); whereas those supported by the 172-216 MHz band (Part 74.802) represent strictly broadcast applications (e.g., television, film production, cable, reporting).

CHANNELING PLANS AND PROVISIONS

There are channeling plans specified for the government assignments in the VHF and UHF bands in question (NTIA Manual, Sections 4.3.7 to 4.3.10). The 162.0125-173.2 MHz VHF subband (which contains all VHF hydrologic channels) consists of 15 blocks of contiguous 25 kHz channels, with variable capacity for block, and with consecutive blocks separated by one 12.5 kHz splinter channel (plus one 25 kHz splinter channel at the end). The 173.4-174 MHz VHF subband (which has no hydrologic channels) consists of one block of contiguous 50 kHz channels without splinter channels.

The entire 406.1-420 MHz UHF band consists of four blocks of contiguous 25 kHz channels, with variable capacity for block, and with consecutive blocks separated by one 25 kHz splinter channel (plus one 25 kHz splinter channel at the end). There are 40 noncontiguous 25 kHz channels spread throughout the four blocks that are designated for trunked land-mobile operations.

Each of the 15 VHF and 4 UHF splinter channels has its own subset of frequencies within the splinter channel that are designated for narrowband operations requiring less than 5 kHz or 10 kHz bandwidth. There are also VHF and UHF provisions to use interstitial channels for assignments with necessary bandwidths equal to or less than 16 kHz. An interstitial channel is centered at any frequency exactly halfway between two adjacent channels in the channeling plans.

These halfway frequencies can also be authorized for VHF or UHF assignments with necessary bandwidths exceeding 16 kHz, but not 50 kHz (VHF) or 100 kHz (UHF). There are also two VHF subbands (406.4875-407.1125 and 416.4375-416.7625 MHz) which have no hydrologic channels, and can be authorized for wideband operation without any limit specified.

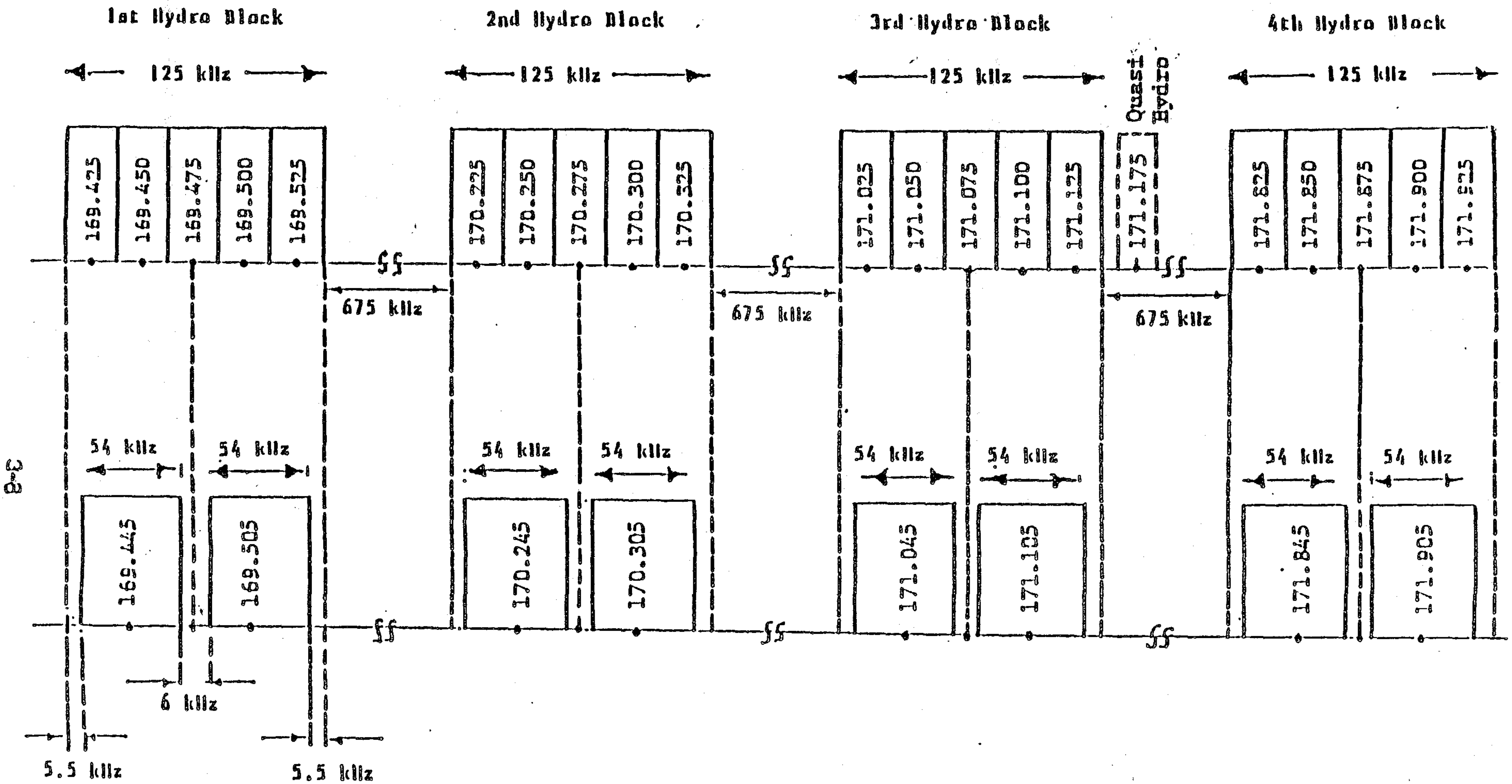
HYDROLOGIC CHANNELING PLANS

The channeling plan for the 20 VHF hydrologic channels consists of four separate hydro blocks as shown in Figure 3-1. Each block supports five hydrologic channels, which represents a bandwidth occupancy of 25 kHz per channel and 125 kHz per block. There is also the one quasi-hydrologic 25 kHz channel isolated from the hydro blocks. There are no splinter channels within any of the hydro blocks.

The eight VHF wireless microphone channels are allocated a 54 kHz maximum bandwidth per channel (NTIA Manual, Section 4.3.2). Their channeling plan consists of two microphone channels located inside each hydro block as shown in Figure 3-1, with a 6 kHz margin between the two microphone channels, and a 5.5 kHz margin at the block edges. The wireless microphones also have a ± 32.5 kHz emission span limit specified, which corresponds to a ± 5.5 kHz frequency stability to maintain their emissions within the 125 kHz hydro block.

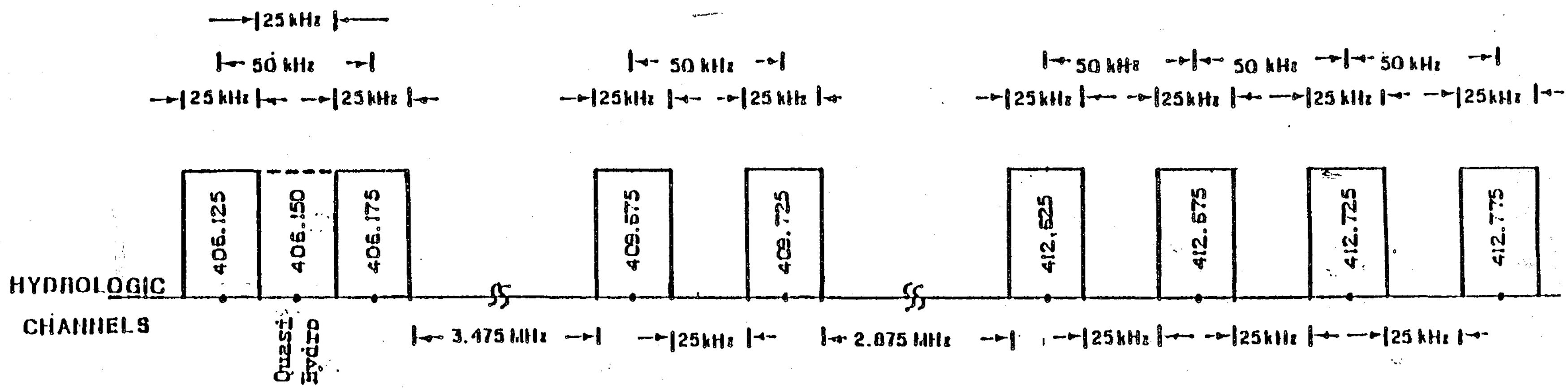
This arrangement mitigates the mutual interference potential between the wireless microphone operations and other services in the band. Each hydro block essentially represents a spectral umbrella that decreases the interference susceptibility of the microphone channels inside the block, besides restricting the wireless microphone emissions to within the hydro block. The significance is that any notable reduction of the single (125 KHz) or total (500 kHz) block occupancy (e.g., using narrower hydro channels or moving them to another band) would remove the umbrella span provided for some or all of the wireless microphone channels, and enhance the mutual interference potential with other services.

The channeling plan for the eight UHF hydrologic channels is shown in Figure 3-2, along with the one quasi-hydrologic channel. The eight hydrologic channels form three groups of two or four noncontiguous 25 kHz channels per group. There is a 50 kHz separation in center



Note: The hydrologic and wireless microphone channel frequencies are in MHz.

Figure 3-1. VHF Hydrologic Channeling Plan
(Top: Hydrologic Channels, Bottom: Wireless Microphone Channels)



Note: The hydrologic channel frequencies are in MHz.

Figure 3-2. UHF Hydrologic Channeling Plan

frequency between the channels within a group, which leaves a 25 kHz gap between such channels. The quasi-hydrologic channel occupies the first 25 kHz gap.

The other 25 kHz gaps currently support nonhydrologic mobile and land-mobile assignments. These gaps also imply that the UHF hydro groups cannot be regularly used to provide contiguous overlap with wireless microphone operations as done in the VHF band. Only the first group would provide a 75 kHz span (and only because of the quasi-hydrologic channel), so that only one 54 kHz microphone channel could be blocked.

FREQUENCY ASSIGNMENT PROCEDURES

The Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data is responsible for coordinating the hydrologic channel use requests, and for providing comments on such requests to the Frequency Assignment Subcommittee (FAS) and the Federal Communications Commission (FCC), (NTIA Manual, Section 8.4.6). The Hydrology Subcommittee has a Hydrologic Radio Frequency Coordination Group to process the hydrologic channel requests, with a coordinator that chairs the group and acts as the applicant go-between.

The hydrologic channel operation requests can also be submitted to FAS, without necessarily including all the information provided to the Hydrology Subcommittee. These requests will be tabled until the coordination process of the Hydrology Subcommittee provides comments to the FAS Secretariat. The FCC is to ensure that the nongovernment requests include the sponsoring government agency in the application submitted.

The Hydrology Subcommittee coordination process is applicable to the 20 VHF and 8 UHF hydrologic channels listed in TABLE 3-5. Coordination with the Hydrology Subcommittee is not required for the 1 VHF and 1 UHF meteorological and quasi-hydrologic channels listed in TABLE 3-5 (NTIA Manual, Section 4.3.3). The wireless microphone assignments are handled by the Frequency Assignment Subcommittee, without any coordination by the Hydrology Subcommittee required (NTIA Manual, Section 4.3.2).

SECTION 4

HYDROLOGIC/NONHYDROLOGIC AND WIRELESS MICROPHONE ASSIGNMENTS

HYDROLOGIC/NONHYDROLOGIC ASSIGNMENTS

The Government Master File (GMF) was investigated to develop a proper perspective of the hydrologic assignments and channel usage by government and nongovernment agencies. The following types of assignments were found in the GMF records:

- Hydrologic operations assigned to hydrologic channels
- Nonhydrologic operations assigned to hydrologic channels
- Hydrologic operations assigned to nonhydrologic channels

The hydrologic operations are distinguished in the GMF records by the letter H included in the station class designator for at least one of the record stations. There can be more than one station per assignment, or more than one emission per station, as described later. Hence, careful accounting should be made when analyzing records or tallying populations, so as to avoid erroneous or misleading scenario descriptions.

DISTRIBUTION OF ASSIGNMENTS AND CHANNEL USAGE

The population and distribution of the assignments in question is shown in Figures 4-1 (VHF) and 4-2 (UHF), along with the wireless microphone assignments. The hydrologic versus nonhydrologic operation breakdown is also provided for the hydrologic channels in each figure. There is a total of 3117 (VHF) and 378 (UHF) hydrologic channel assignments, and the hydrologic operations represent 88% (VHF) and 96% (UHF) of these assignments.

There are also hydrologic operations in 28 (VHF) and 11 (UHF) nonhydrologic channels, representing 12% (VHF) and 4% (UHF) of all hydrologic operations in the band. In fact, the number of hydrologic operations in nonhydrologic channels (384 VHF, 15 UHF) is very close to the number of nonhydrologic operations in hydrologic channels (372 VHF, 16 UHF). A summary of the hydrologic/nonhydrologic operations and channel usage is presented in TABLE 4-1.

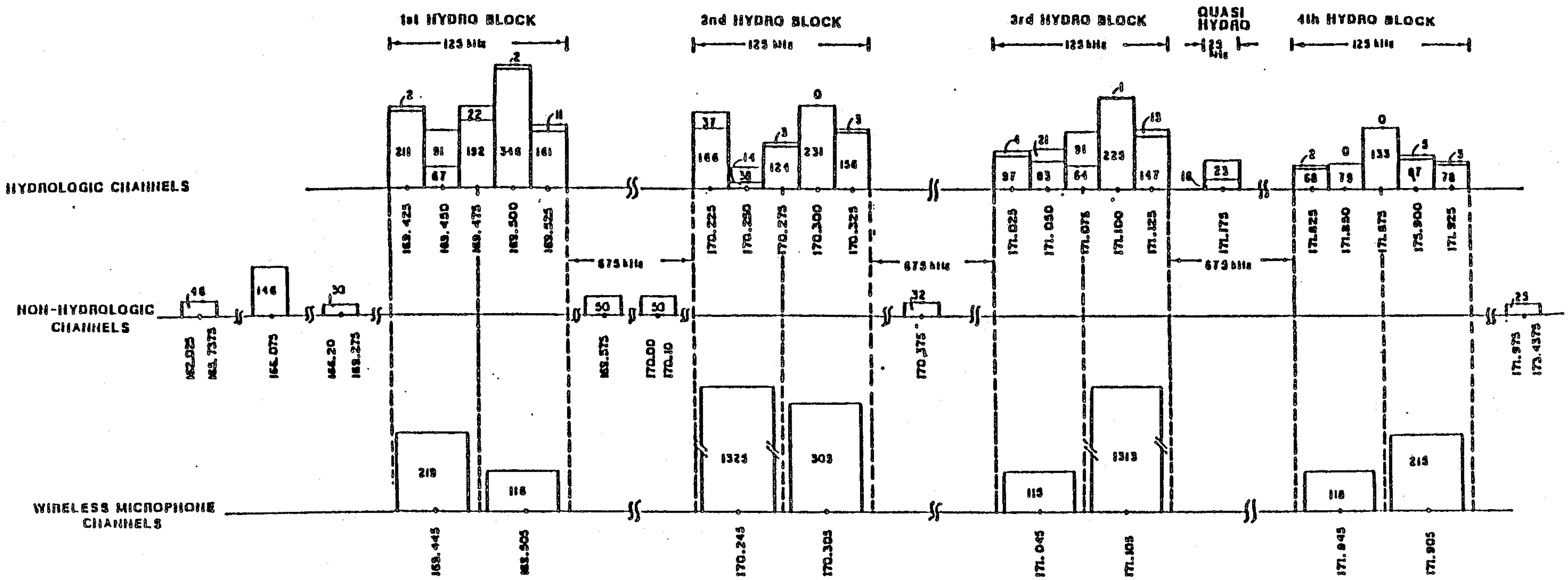


Figure 4-1. Distribution and population of VHF assignments

Top: Hydrologic/Nonhydrologic assignments in hydrologic channels (Note: top number for nonhydrologic, bottom number for hydrologic)

Middle: Hydrologic assignments in nonhydrologic channels

Bottom: Wireless microphone assignments in wireless microphone channels

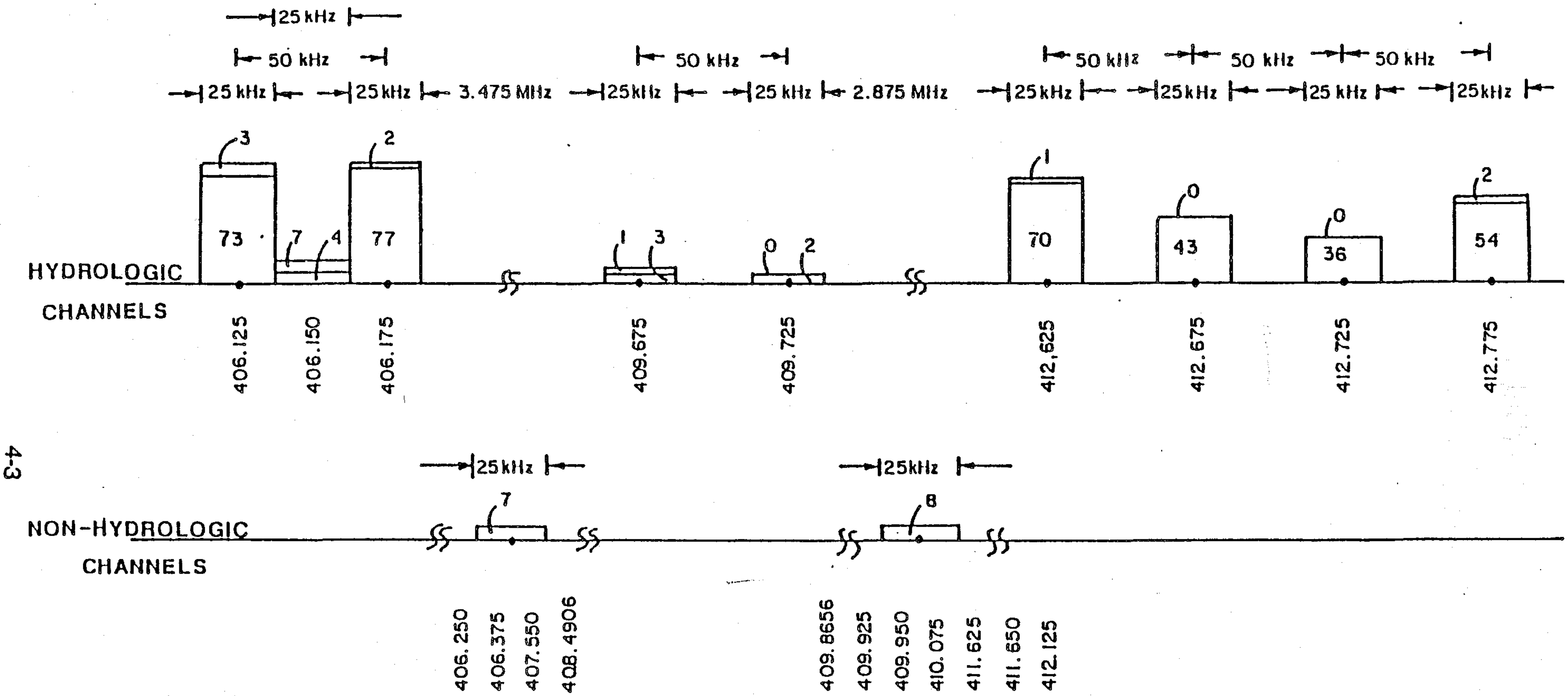


Figure 4-2. Distribution and population of UHF assignments

Top: Hydrologic/Nonhydrologic assignments in hydrologic channels
(Note: top number for nonhydrologic,
bottom number for hydrologic)

Bottom: Hydrologic assignments in nonhydrologic channels

TABLE 4-1

SUMMARY OF HYDROLOGIC/NONHYDROLOGIC ASSIGNMENTS AND CHANNEL USAGE

	VHF	UHF
Hydrologic Operations in Hydrologic Channels	2745	362
Hydrologic Operations in Nonhydrologic Channels	384	15
Nonhydrologic Operations in Hydrologic Channels	372	16
Hydrologic Operations in Hydrologic and Nonhydrologic Channels	3129	377
Hydrologic and Nonhydrologic Operations in Hydrologic Channels	3117	378
Wireless Microphone Operations (Wireless Microphone Channels)	3721	0

DISTRIBUTION OF ASSIGNMENTS BY AGENCY AND FREQUENCY

The breakdown of hydrologic versus nonhydrologic assignments by agency is shown in TABLES 4-2 (VHF) and 4-3 (UHF) for the hydrologic channels. The nonhydrologic operations are spread over various agencies and frequencies, with three government agencies using hydrologic channels exclusively for nonhydrologic operations. Nongovernment agencies also have nonhydrologic assignments, though still a small percentage compared to their hydrologic assignments.

The agency breakdown of the hydrologic operations in nonhydrologic channels is presented in TABLE 4-4 (VHF) and 4-5 (UHF). All but one of the agencies with hydrologic assignments in hydrologic channels also have hydrologic assignments in nonhydrologic channels. There are also two agencies with one hydrologic assignment each on nonhydrologic channels, yet none in hydrologic channels.

The agency breakdown for the wireless microphone assignments is shown in TABLE 4-6. Nongovernment agencies represent 98% of these assignments, with the rest spread over various

TABLE 4-2
(page 1 of 2)

HYDROLOGIC/NON-HYDROLOGIC ASSIGNMENTS IN VHF HYDROLOGIC CHANNELS

	FREQUENCIES (MHz)									
AGENCIES	169.425	169.450	169.475	169.500	169.525	170.225	170.250	170.275	170.300	170.325
AGRI-CULTURE 82/0	5 / 0	8 / 0	5 / 0	2 / 0	5 / 0			15 / 0	6 / 0	
ARMY 449/8	30 / 0	39 / 0	8 / 0	17 / 0	33 / 0	14 / 0		24 / 0	10 / 0	9 / 1
COMMERCE 723/4	49 / 1	3 / 1	30 / 0	126 / 0	21 / 0	24 / 0	7 / 0	41 / 0	63 / 0	1 / 0
ENERGY 35/2				24 / 0						
INTERIOR 93/7	11 / 0	7 / 0		2 / 0		15 / 0			4 / 0	
IBWC 6/1	6 / 1									
NAVY 3/0										
NON-GOVT 1261/89	100 / 0		138 / 1	163 / 0	99 / 11	107 / 37	7 / 17	44 / 1	148 / 0	146 / 2
NRC 0/63			0 / 21				0 / 21			
POSTAL SERVICE 0/1										
SENATE 0/1										
TVA 93/0	10 / 0	10 / 0	11 / 0	12 / 0	3 / 0	6 / 0				
OTHERS 0/196		0 / 90		0 / 2				0 / 2		
TOTALS 2745/372	211 / 2	67 / 91	192 / 22	346 / 2	161 / 11	166 / 37	14 / 38	124 / 3	231 / 0	156 / 3

HYDROLOGIC/NON-HYDROLOGIC ASSIGNMENTS IN VHF HYDROLOGIC CHANNELS

	FREQUENCIES (MHz)										QUASI HYDRO
AGENCIES	171.025	171.050	171.075	171.100	171.125	171.825	171.850	171.875	171.900	171.925	171.175
AGRI-CULTURE	6 / 0	5 / 0	20 / 0	3 / 0							2 / 0
ARMY	39 / 0	1 / 0		81 / 0	2 / 0	5 / 0	12 / 0	74 / 0	46 / 0	1 / 1	4 / 6
COMMERCE	33 / 0	49 / 0	19 / 0	98 / 0	25 / 0	38 / 0	37 / 0	8 / 0	21 / 1	30 / 1	
ENERGY						11 / 0					0 / 2
INTERIOR	17 / 3	4 / 0	16 / 0	4 / 0		0 / 2				3 / 0	10 / 2
IBWC											
NAVY				3 / 0							
NON-GOVT	2 / 1	24 / 0	9 / 0	36 / 1	120 / 13	8 / 0	22 / 0	39 / 0	9 / 4	40 / 1	
NRC		0 / 21									
POSTAL SERVICE											0 / 1
SENATE											0 / 1
TVA						6 / 0	8 / 0	12 / 0	11 / 0	4 / 0	
OTHERS			0 / 91								0 / 11
TOTALS	97 / 4	83 / 21	64 / 91	225 / 1	147 / 13	68 / 2	79 / 0	133 / 0	87 / 5	78 / 3	16 / 23

TABLE 4-3

HYDROLOGIC/NONHYDROLOGIC ASSIGNMENTS IN HYDROLOGIC UHF CHANNELS

AGENCIES	FREQUENCIES								QUASI HYDRO
	M406.125	M406.175	M406.675	M409.725	M412.625	M412.675	M412.725	M412.775	M406.150
AGRICULTURE 5/0		2/0			2/0				1/0
ARMY 16/0	2/0	3/0			1/0	1/0		9/0	
COMMERCE 33/0	2/0	22/0			2/0			7/0	
ENERGY 2/2	1/0						1/0		0/2
FEMA 0/1									0/1
INTERIOR 52/7	12/2	30/1	2/1		2/0			4/0	2/3
NAVY 1/0									1/0
NON-GOVERNMENT 108/5	51/1	14/1	1/0		24/1	8/0	10/0	0/2	
TVA 145/0	5/0	6/0		2/0	39/0	34/0	25/0	34/0	
OTHER 0/1									0/1
TOTALS 362/16	73/3	77/2	3/1	2/0	70/1	43/0	36/0	54/2	4/7

TABLE 4-4

HYDROLOGIC ASSIGNMENTS IN VHF NONHYDROLOGIC CHANNELS

AGENCIES	NUMBER OF ASSIGNMENTS	FREQUENCIES (MHz)
AGRICULTURE	39	164.1500, 166.6750 169.2750, 169.5750 170.3750
AIR FORCE	2	173.4375
ARMY	43	163.4125, 165.0375 165.1625, 169.5750 170.3750, 171.9750
COMMERCE	157	162.1500, 163.3000 166.0750, 169.0250 170.1000
ENERGY	1	163.7937
FAA	2	165.7375
INTERIOR	117	163.0250, 164.4250 164.4750, 166.2000 166.8000, 166.9250 169.5750, 170.0000 170.3750, 171.9750
INTERNATIONAL BORDER AND WATER COMMISSION	6	172.4750, 173.1750
NON-GOVERNMENT	14	169.5750, 170.3750
TENNESSEE VALLEY AUTHORITY	3	162.0250, 172.0250
TOTAL	384	28 CHANNELS

TABLE 4-5

HYDROLOGIC ASSIGNMENTS IN UHF NONHYDROLOGIC CHANNELS

AGENCIES	NUMBER OF ASSIGNMENTS	FREQUENCIES (MHz)
ARMY	2	406.2500, 407.5500
ENERGY	2	408.4906, 409.8656
INTERIOR	5	406.2500, 411.6250 411.6500
INTERNATIONAL BORDER AND WATER COMMISSION	1	412.1250
NON-GOVERNMENT	5	406.2500, 406.3750 409.9250, 409.9500 410.0750
TOTAL	15	11 CHANNELS

TABLE 4-6

WIRELESS MICROPHONE ASSIGNMENTS

AGENCIES (Total Assignments)	FREQUENCIES (MHz)							
	169.4450	169.5050	170.2450	170.3050	171.0450	171.1050	171.8450	171.9050
AIR FORCE (14)	3	2	1	1	1	2	1	3
ARMY (14)	1	3	1	2	2	3	1	1
ADMINISTRATIVE OFFICE OF THE U.S. COURTS (2)		1	1					
COMMERCE (2)	1					1		
ENERGY (6)		2			2			2
FEDERAL EMERGENCY MANAGEMENT AGENCY (6)	1	1			1	1	1	1
HEALTH AND HUMAN SERVICES (2)	1							1
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (3)		1	1					1
NAVY (5)	1		1			2	1	
NON-GOVERNMENT (3,653)	209	105	1318	296	107	1303	113	202
STATE (4)	1			1	1		1	
U.S. POSTAL SERVICE (2)		1						1
VETERANS ADMINISTRATION (7)	1		2		1			3
OTHER (1)				1				
TOTALS (8,721)	219	116	1325	301	115	1312	118	215

government agencies. The total number (3721) of wireless microphone assignments is similar to the total number (3129) of hydrologic operation assignments (hydrologic/nonhydrologic channels), and to the total number (3117) of hydrologic channel assignments (hydrologic/nonhydrologic operations).

SECTION 5

STATION CLASSES AND EMISSION BANDWIDTHS

STATION CLASS OCCURRENCES

The GMF records were analyzed to identify the station classes and emission characteristics (modulation, bandwidth, power) associated with the assignments in question. A detailed report is presented in APPENDIX A for the hydrologic/nonhydrologic assignments in hydrologic channels, in APPENDIX B for the hydrologic assignments in nonhydrologic channels, and in APPENDIX C for the wireless microphone channels.

The station classes encountered in these assignments represent the Fixed, Mobile, and Land Mobile Services, plus a few experimental stations not associated with a specific service. The hydrologic/nonhydrologic operation breakdown by service is shown in TABLE 5-1 for the hydrologic channel assignments. The majority of the hydrologic operations correspond to the Fixed Service, and the majority of the nonhydrologic operations correspond to the Mobile and Land Mobile Services. The wireless microphone assignments all correspond to the Land Mobile Service.

TABLE 5-1

HYDROLOGIC/NONHYDROLOGIC OPERATIONS IN HYDROLOGIC CHANNELS

	VHF	UHF
Fixed Service	2742/100	362/15
Mobile Service	3/191	0/0
Land Mobile Service	0/75	0/1
Experimental	0/6	0/0
TOTALS	2745/372	362/16

Note: There are 3117 assignments in VHF hydrologic channels, and 378 assignments in UHF hydrologic channels.

A summary of the distinct station classes found in the assignments is given in TABLE 5-2 for reference purposes. The total number of assignments is less than the total number of stations, because there can be one, two, or more stations per assignment. The number of emissions per assignment also varies, since there can be distinct emissions associated with distinct or identical station classes in a given assignment.

TABLE 5-2

SUMMARY OF STATION CLASSES

Fixed Service:	FX	- Fixed Station
	FXR	- Fixed Repeater Station
	FXD	- Fixed Telecommand Station
	FXE	- Fixed Telemetering Station
	FXH	- Fixed Hydrologic/Meteorologic Station
	FXHR	- Fixed Hydrologic/Meteorologic Repeater Station
Mobile Service:	FL	- Land Station
	FLR	- Land Repeater Station
	MO	- Mobile Station
	MOP	- Mobile Portable Station
	MOH	- Mobile Hydrologic/Meteorologic Station
Land Mobile Service:	FB	- Base Station
	ML	- Land Mobile Station
	MLP	- Land Mobile Portable Station
No Specific Service:	XD	- Experimental Development Station
	XR	- Experimental Research Station
	XT	- Experimental Testing Station

Note: Each assignment may contain more than one station class, and more than one emission per station class.

The hydrologic operations exhibit one or two stations per assignment. The single occurrences usually have a fixed hydro station (FXH or FXHR), with only three mobile hydro stations (MOH) being the exception. The dual occurrences predominate in hydrologic operations, and usually consist of a fixed hydro station (FXH or FXHR) plus a fixed station (FX or FXR), though the pairings can happen in different ways (e.g., FXH/FX, FXHR/FX, FXHR/FXR).

The hydrologic station duality happens because two distinct emissions are regularly employed in hydrologic operations, as described later. The dual station occurrences can also consist of the same station class (e.g., FXH/FXH, FXHR/FXHR) with different emissions per station. The emissions can vary in modulation method or assigned bandwidth, as well as in the power specification.

A similar diversity exists with the nonhydrologic assignments in hydrologic channels, which exhibit one, two, or more stations per assignment. The single occurrences consist of a fixed station (FX, FXD, FXE, FXR), and the dual or multiple occurrences consist of a set of mobile or land mobile stations per assignment (e.g., FB/ML or MO/MOP for dual, FL/FLR/MO or FL/FLR/MO/MOP for multiple). Each set can further double the record entries by having two emission options per station class in the set.

The distribution of station class occurrences by agency and frequency is given in APPENDIX A, TABLES A-1 (VHF) and A-2 (UHF) for the hydrologic/nonhydrologic assignments in hydrologic channels, and in APPENDIX B, TABLES B-3 (VHF) and B-4 (UHF) for the hydrologic assignments in nonhydrologic channels. The station class distribution for the wireless microphone assignments is given in APPENDIX C, TABLE C-1.

These tables clearly illustrate the diversification (and potential confusion) introduced by the different station class and emission option combinations that regularly appear in the hydrologic/nonhydrologic operation assignments. For example, there are six distinct types of dual station occurrences for hydrologic operations, and there can be up to eight entries per assignment (due to four distinct station classes and two emission designators) for nonhydrologic operations.

HYDROLOGIC EMISSION BANDWIDTHS

The hydrologic operations utilize two specific emissions for data and voice information transfer. An FSK/FM signal with a digital data subcarrier (F2D emission designator) supports data collection links from remote sites as well as data backbone communications between operation centers. An FM signal with single-channel voice (F3E emission designator) also supports voice communications between operation centers.

A 16 kHz emission bandwidth is the predominant mode for both emission types cited above, and it represents 78% (VHF) and 66% (UHF) of all the hydrologic operation emissions specified in hydrologic channels. A 15 kHz bandwidth also appears in a few assignments (0.2% VHF, 5.4% UHF), and can also support the two emission types in question, as described later. A 20 kHz bandwidth is the only higher value assigned, and it appears only in nongovernment assignments representing 20% (VHF) and 10% (UHF) of all hydrologic operation emissions in hydrologic channels.

The only narrower bandwidth corresponding to government hydrologic operations in hydrologic channels is 10 kHz, which represents 0.3% (VHF) and 16% (UHF) of the emissions in such assignments. These 10 kHz emissions have been reported to be very early systems that were adapted in-house many years ago to support narrowband operations and are being phased out of existence.

There are also a few narrowband hydrologic operations corresponding to nongovernment assignments in hydrologic channels. The assigned bandwidths are 5.6 kHz (0.2% VHF, 1.6% UHF), 5 kHz (0.3% UHF), 4.5 kHz (1.3% VHF), and 2.5 kHz (0.3% VHF), and they represent less than 2% of the hydrologic operation emissions in hydrologic channels for either band.

A similar pattern is exhibited by hydrologic emissions in nonhydrologic channel assignments. A 16 kHz bandwidth represents 91% (VHF) and 55% (UHF) of such emissions, with 15 kHz representing 4.6% (VHF) and 5% (UHF). A 20 kHz bandwidth is the higher value assigned, and only appears in nongovernment operations representing 3.3% (VHF) and none (UHF) of such emissions. The narrowband emissions with significant population have assigned bandwidths of 12 kHz (25% UHF) and 10 kHz (2% VHF).

The nonhydrologic emissions in hydrologic channels have emission designators given by A1B (1 VHF assignment), F1D (5 VHF and 2 UHF assignments), L2D (44 VHF assignments), and F1E/F3E (196 VHF assignments). A 16 kHz bandwidth is assigned to 99.8% (VHF) and 100% (UHF) of such emissions, with a 20 kHz bandwidth representing the remaining 0.2% (VHF).

WIRELESS MICROPHONE EMISSION BANDWIDTHS

The wireless microphone emissions are allowed a 54 kHz maximum bandwidth, but this value does not represent the norm in the existing assignments, as illustrated in Figure 5-1. The predominant value is a 20 kHz emission bandwidth, which represents 70.8% of the wireless microphone assignments. The next values in population percentage are 54 kHz (12.6%), 8 kHz (9.1%), 15 kHz (5.5%), with other values representing only 2% of the assignments.

The emission bandwidth distribution of Figure 5-1 shows 86.2% not exceeding 20 kHz, so that most of the wireless microphone population occupies much less than the 54 MHz bandwidth allowed. The remaining wideband emissions are evenly spread over all the eight microphone channels available, so that each wideband channel supports a few wideband and many narrower microphone emissions.

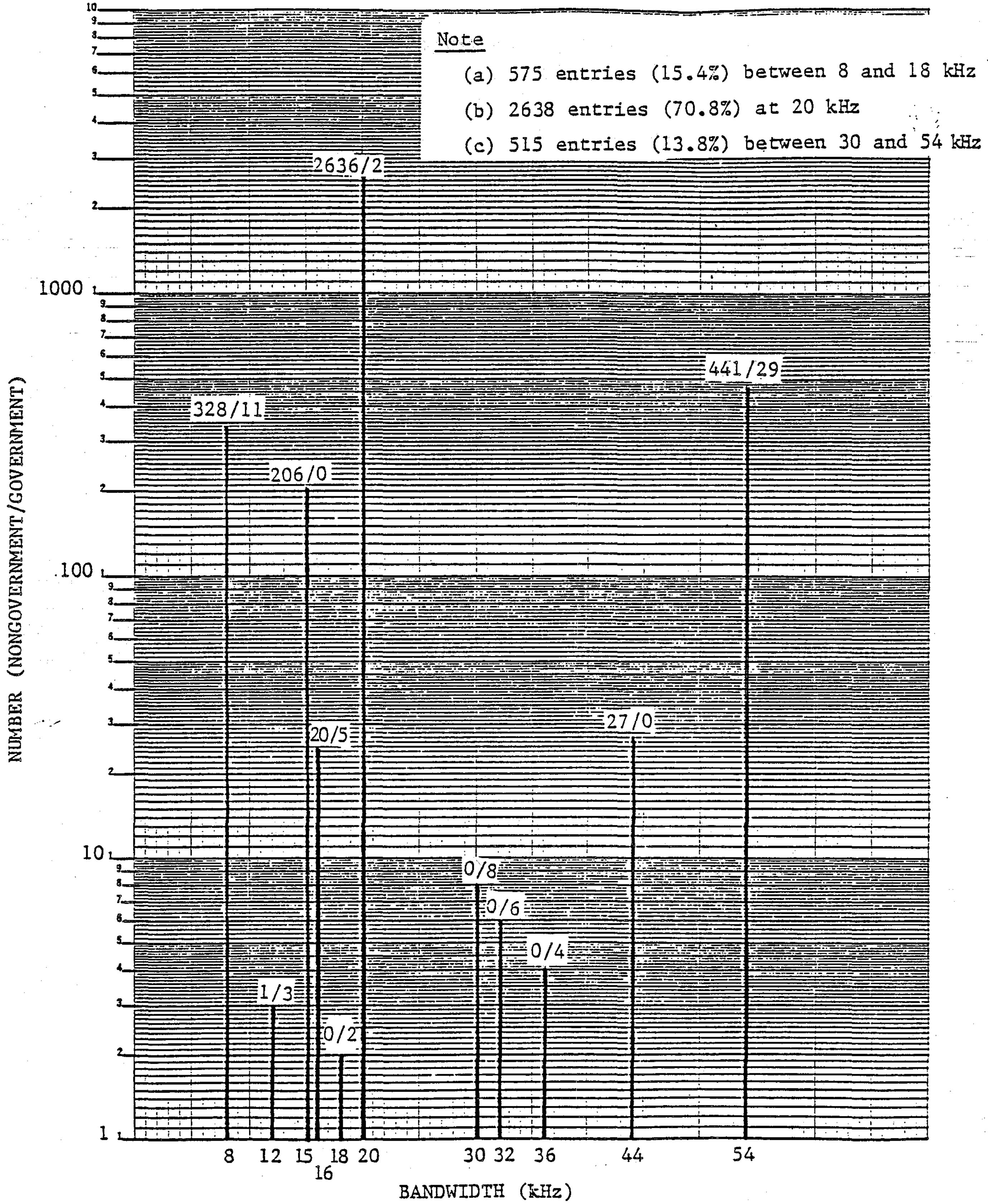


Figure 5-1. Emission bandwidth population for wireless microphone assignments

A more spectrally efficient arrangement would result from having distinct channel bandwidths, and making bandwidth-selective assignments accordingly. For example, most microphone channels could be split into two 27 kHz channels that would support most of the microphone emissions (20 kHz or less), while a few 54 kHz channels would remain to support the wideband emissions (one or two would suffice statistically).

The other modification required would be to tighten the drift tolerance of the microphone emissions. The current regulations limit the emissions to be within ± 32.5 kHz of their assigned frequencies, which represents a ± 5.5 kHz frequency drift limit since a 54 kHz bandwidth is allowed. This limit is intended to maintain the microphone emissions within the hydro block umbrella span up to the edges (see Figure 3-1). However, such tolerance also implies a VHF frequency stability of about 30 ppm (30×10^{-6}) which can be improved.

A ± 5.5 kHz drift would create a 31 kHz bandwidth span to be provided for the 20 kHz predominant emission bandwidth of the wireless microphones. For example, this tolerance would have to be tightened to ± 3.5 kHz to limit the span to 27 kHz (split-channel) for the 20 kHz or less emission bandwidths. This would represent a VHF frequency stability of about 20 ppm (20×10^{-6}) which is certainly feasible.

Another spectrally efficient arrangement would be to preserve the existing center frequencies of the wireless microphones, but narrowband most of the channels instead of splitting them. For example, a 25 kHz channel bandwidth would still support most of the microphone emissions (20 kHz or less), and only require a ± 2.5 kHz drift limit which represents about 15 ppm (15×10^{-6}) frequency stability (also feasible).

Moreover, a third 25 kHz microphone channel can then be added and centered between the two 25 kHz narrowband microphone channels inside a hydro block, while also providing a 5 kHz guard band between the central channel and its two adjacent channels. A hydro block would support three 25 kHz channels instead of four 27 kHz channels, but there would be no need to shift the current microphone channel frequencies. Only the new central frequency would have to be added as an allotted channel inside each block.

The possibility of narrowbanding all wireless microphone channels, instead of preserving some 54 kHz channels, is another alternative approach. Each hydro block would support three 25 kHz channels, while preserving the current channel frequencies and adding the central one. The wideband microphone assignments would still be allowed in the current channel frequencies and the central one, and distributed in all the hydro blocks as presently done so that bandwidth-selective assignments are not required.

The fact that most microphone emissions are much narrower than their 54 kHz allowed bandwidth also implies that overspan is being provided by the hydro block umbrella to most microphones for the sake of a few. Even if a ± 5.5 kHz drift is assumed, most of the microphone emissions need no more than 31 kHz span, yet 63 kHz span per channel is being provided to accommodate the few wider microphones.

This span scenario is not only spectrally inefficient, but it is also dangerous since any reduction in the hydro block span (e.g., hydrologic narrowbanding or relocating) automatically leaves some microphones unblocked. The channeling plan alternatives just presented for the wireless microphones would feature better control potential, since the predominantly narrower microphones would have more channel options, and the fewer wideband microphones could be lumped together if necessary.

SECTION 6

HYDROLOGIC OPERATIONS: FLASH FLOOD WATCH AND WARNING SYSTEMS

HYDROLOGIC OPERATIONS OVERVIEW

Hydrologic operations presently conducted by government and sponsored nongovernment agencies represent a valuable nationwide service provided to state and local communities. These operations support environmental monitoring and forecasting, flood watch and warning, nuclear and fossil plants, stream and water analysis, etc. The community impact can be critical since the service outcome includes flash flood alarms, disaster prevention and control, safety-of-life decisions, etc.

Hydrologic networks serving state and local communities have evolved into well structured configurations that efficiently utilize the hydrologic channels and the community resources. The hydrologic channels support remote sites, repeater stations, operation centers, backbone nodes, etc., while the community resources augment the network coverage or service application through other available communication (e.g., microwave links, telephone lines) or processing (e.g., computer facilities, modem interfaces) capabilities.

The majority of the hydrologic operations correspond to flash flood watch (forecasting) and warning (alarm) systems. The hydrologic networks involved typically have state (e.g., east coast) or local (e.g., west coast) configurations, and the present trends are towards integration of existing networks and service expansion to central regions, besides extending specific networks to meet community needs. There are many common elements that motivate a substantial network integration potential, but also some differences that will require effective coordination to avoid independent developments and ramifications.

Hydrologic user groups exist and meet regularly, with new technical standards, operation logistics and hydrologic applications emerging and proliferating to create new emission specifications, channel usage, and equipment requirements. Hydrologic equipment manufacturers and market representatives currently implement and distribute a variety of novel designs that enhance the throughput capabilities (higher data rates, multichannel operation) and the application scope (multiple parameter sensors, hybrid data rate support). The hydrologic operations scenario is presently in a dynamic state and the forthcoming status accommodation can have an impact on spectrum management concerns.

Hydrologic operations presently rely on the VHF and UHF hydrologic channels to support terrestrial data collection and data/voice communication links. Other alternatives such as satellite or meteor-burst communication links have been found to be incompatible with the low-power transmitter stations and real-time information transfer requirements of the current hydrologic operations. The modification of the hydrologic equipment to use these other links would not be cost-effective and would require a total revision of most system specifications and/or operation logistics, besides massive station equipment replacement.

NATIONAL WEATHER SERVICE (NWS)

NWS represents the Federal Government authority for functions relating to flood warnings, as mandated by Congress. In particular, the NWS hydrology program has as its primary objective to mitigate the loss of life and property damages by timely river and flood forecasts and warnings. The operations include "flash flood watch" to inform the public via state/local agencies of troublesome hydrological and meteorological conditions developing in designated areas, and "flash flood warning" to manage imminent or occurring flood conditions that require immediate action.

The NWS flood warning system is spread nationwide, with all states having local coordination or representatives as illustrated in Figure 6-1. A typical interaction between NWS, the local facilities and the public is shown in Figure 6-2, with the ground observation data representing the critical source of information for flood warnings. The use of geosynchronous satellite data would not be timely enough to replace the ground observations, based on the existing capabilities without excessive cost modifications. For example, the satellite information would be distributed with a 2 to 4 hour delay, in contrast to the 15-minute updates being generated by the existing network links, with cost effective adaptations.

The flood watch and warning operations include automated observation sensors, manual reports, data/voice communication links, automated data collection and processing, forecasting software, and alarm distribution systems. These operations support the original flash flood alarm systems, as well as the new Integrated Flood Observing and Warning Systems (IFLOWS) and Automated Local Evaluation in Real Time (ALERT) Systems. An early local alarm system installation is shown in Figure 6-3, with a river station sensor automatically detecting the critical flood level to trigger the community alarm.

INTEGRATED FLOOD OBSERVING AND WARNING SYSTEM (IFLOWS)

IFLOWS has operated since 1979 as a cooperative venture of the Federal Government with state/local governments to support effective networks for flash flood forecasting, warning, and management. The Federal Government provides initial funding and continuing technical advice for the network expansion to serve new communities, who share the development costs with real up-front monies on a 50% basis and are fully responsible for maintenance thereafter.

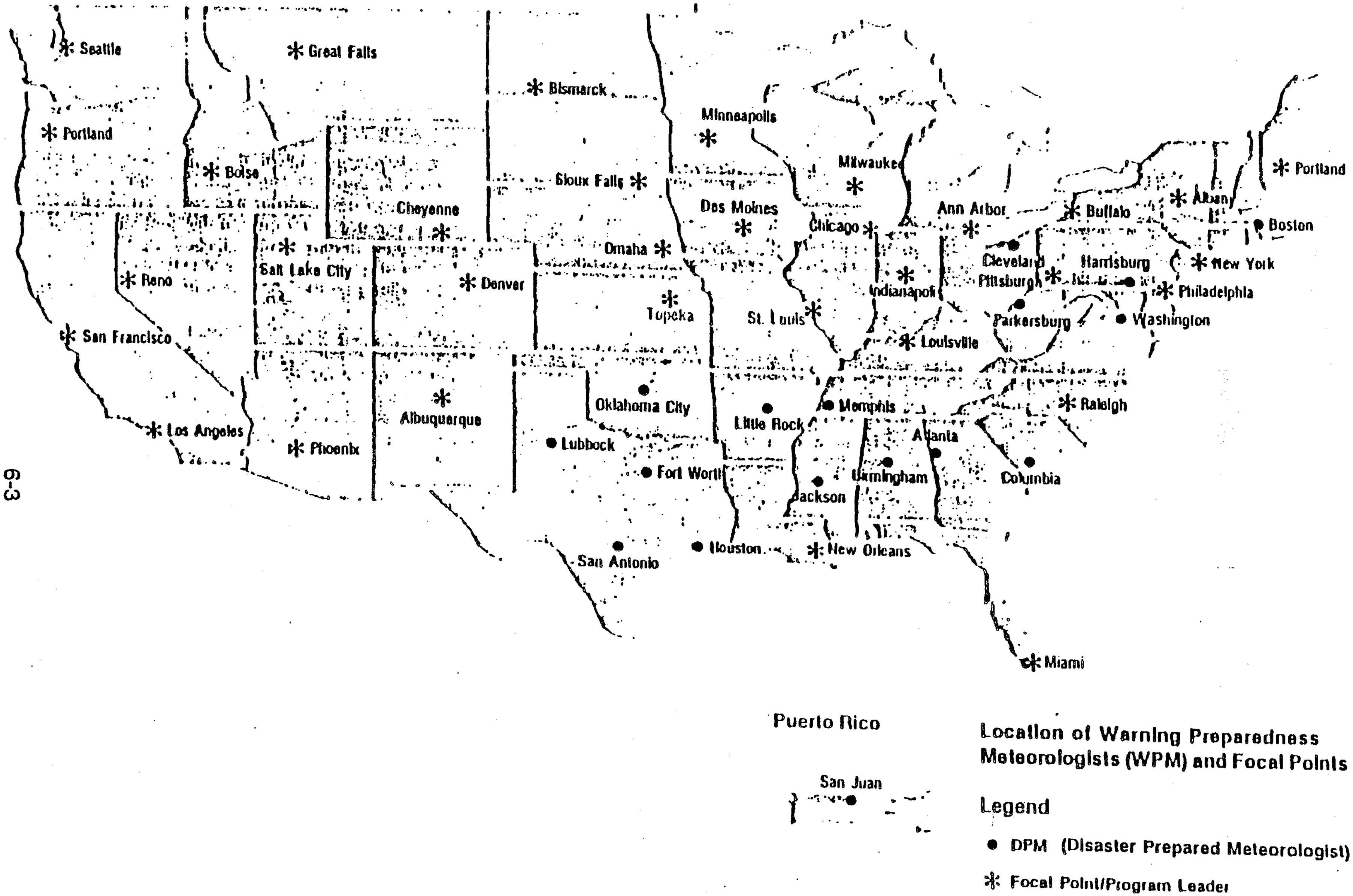


Figure 6-1. NWS nationwide coverage

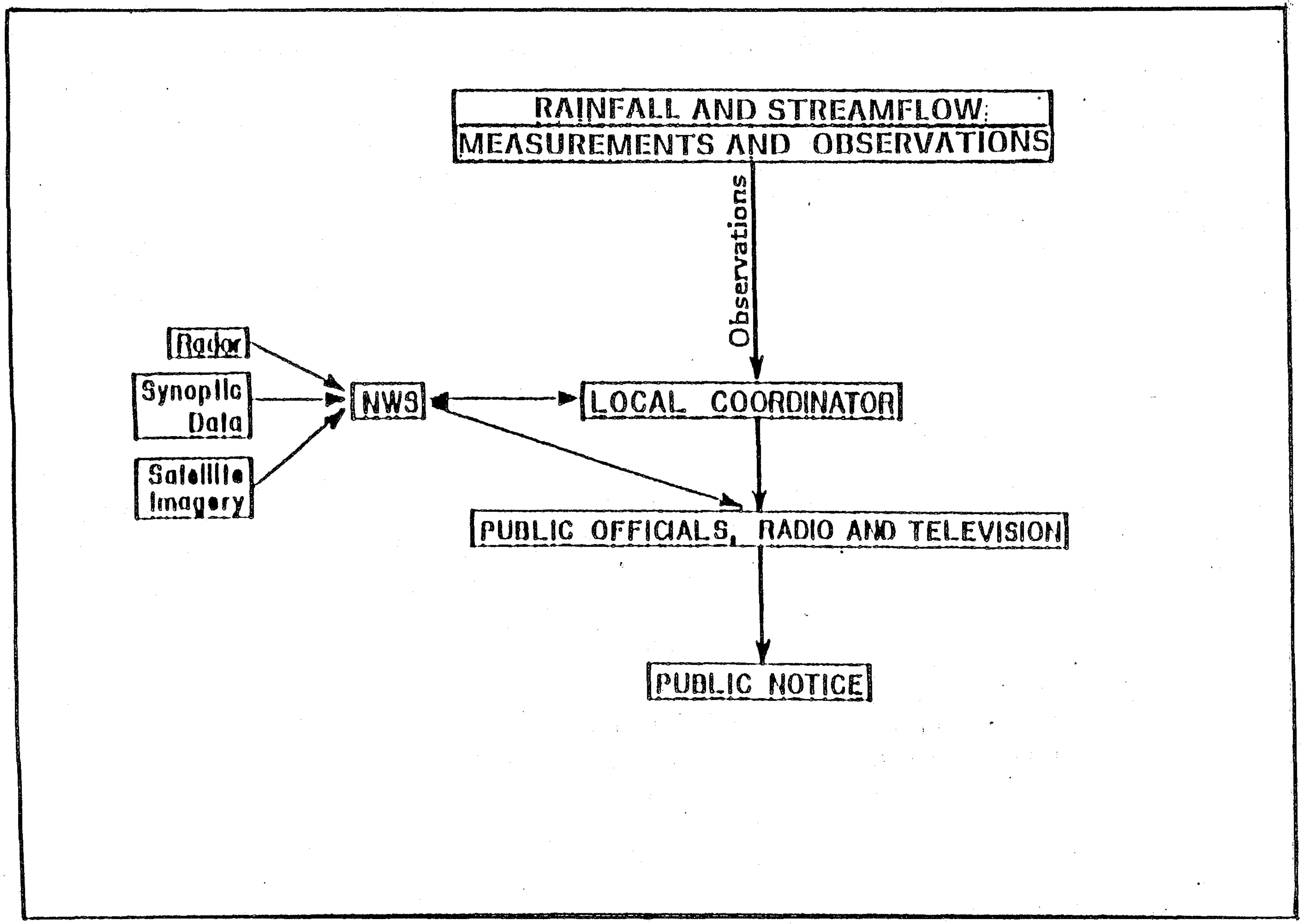


Figure 6-2. NWS community interaction example

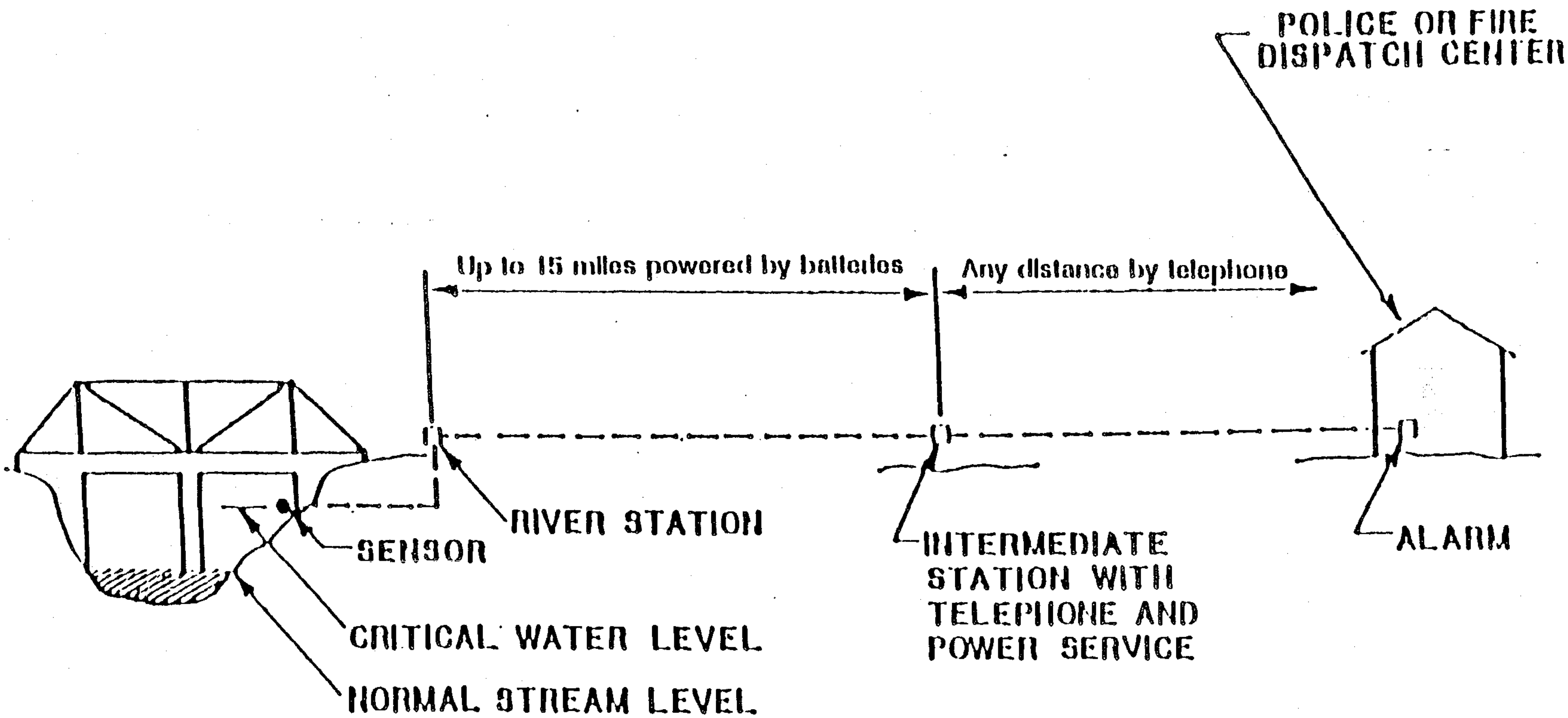


Figure 6-3. Illustration of local flash flood alarm installation

The network expansion is based on priority needs, available funds, and effective cooperation by interested communities. Emergency appropriations by the Federal Government are also possible for special cases or requests.

IFLOWS has served to save lives and property by providing critical information to threatened communities in a timely, accurate, and reliable way. High-resolution remote sensors produce rainfall data that is disseminated along with other messages in 15-minute updates to the network nodes. The latter include local emergency operating centers (EOCs) or NWS offices that are staffed by trained personnel and equipped with computer facilities. The node links support digital data and analog voice communications, with the specific data flow and traffic logistics adapted to accommodate the community needs and resources, or the urgency of the situation.

The basic network elements are the remote sensors and the network nodes as detailed below. The communication links between these elements support a Data Collection Subsystem to transfer the remote observations to data collection nodes, a Data Backbone Subsystem to generate and disseminate the 15-minute message updates within the network, and a Voice Subsystem employed for analog voice communications between the network nodes. Communication between independent networks is also possible via gateway nodes that participate in two distinct networks.

All IFLOWS networks use the radio reporting rain gage (RRRG) as the automated rainfall sensor, as illustrated in Figure 6-4. It features a built-in transmitter and antenna, plus an electromechanical tipping bucket, microprocessor counter, and electronics package that automatically trigger, reset, and recycle the radio transmissions whenever one millimeter of rainfall is accumulated. A 300-baud message is transmitted for about 0.5 seconds by frequency modulating (FM) an RF carrier with a frequency-shift keyed (FSK) audio tone. No transmission occurs unless the one-millimeter rainfall count is exceeded, except for a one-per-day status message that is always transmitted regardless of the rainfall amount.

The 300-baud sensor signals reach remote nodes, either directly or via radio repeaters without signal modification (Data Collection Subsystem). A family of sensors may be handled by a single repeater to extend coverage area. A control node in the network then polls the remote nodes to generate the 15-minute cumulative data and manage the information dissemination, using 1200-baud messages with one-to-ten second durations (Data Backbone Subsystem). These data links also convey text reports, node status, manual observations, etc., besides the rainfall updates. Analog voice links are also employed for emergency or backup communications between the network nodes (Voice Subsystem).

Modems are employed in the Data Collection and Backbone Subsystems for audio signal conversion. The collection nodes have 300-baud receive modems that convert the 2040 Hz

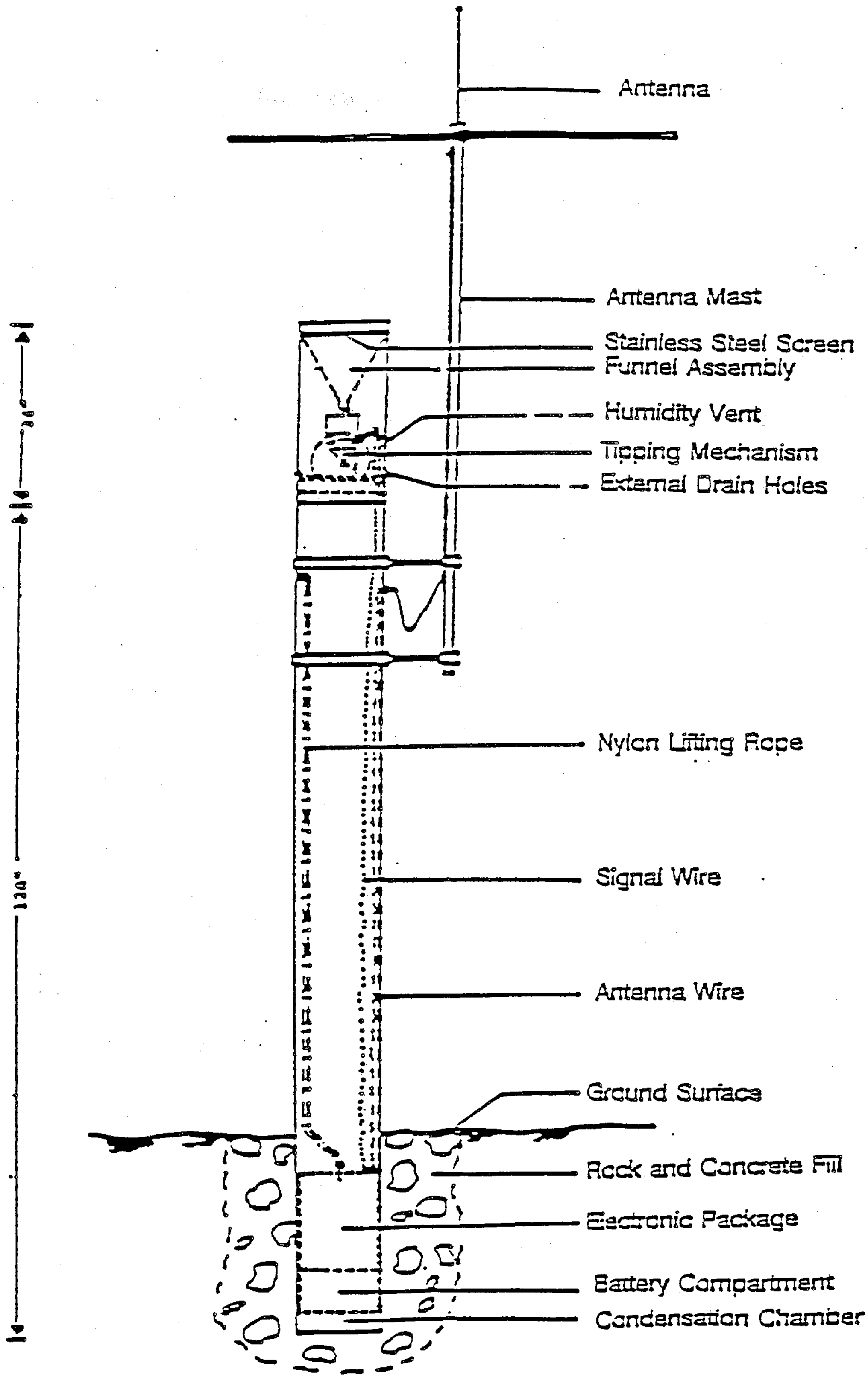


Figure 6-4. Radio reporting rain gage

keyed tone into a binary RS-232C digital signal, as well as 1200-baud transmit/receive modems that can operate at various audio frequencies (600 Hz, 1080 Hz, 1560 Hz, 2520 Hz) for the backbone communications and multiplexing. Voice signals can also be transmitted or received by a collection node for backbone communications.

The radio frequencies reserved as hydrologic channels by the Federal Government are regularly employed in the IFLOWS links, including simultaneous usage of distinct channels in the same network as illustrated in Figure 6-5. These channels are reliable for the Data Collection Subsystem, which has prompted the commercial development and availability of RRRGs in these bands. The early RRRGs had limited address capacity (100 IDs per frequency per coverage area) so that more than one channel could be employed in the Data Collection Subsystem under certain coverage overlap conditions. The present trend is to use a single channel for all data collection links as shown in Figure 6-5.

The Data Backbone and Voice Subsystems use a combination of the hydrologic channels and local/state microwave radio links, because the channels become limited over long distances or rugged terrain (e.g., typical VHF links are limited to 50 miles). Satellite radio or telephone lines can also be used in the Data Backbone and Voice Subsystems to provide links when microwave radio is unavailable. An example of network usage of hydro channels, microwave links, and telephone lines is shown in Figure 6-6. Typical design goals are a 20 dB or greater performance margin for each end-to-end path to support a 90% communications reliability.

AUTOMATED EVALUATION IN REAL TIME (ALERT)

ALERT systems perform the same flash flood functions and rely on the same network operations and communication subsystems as IFLOWS with some differences. ALERT is essentially concentrated in the West Coast (California) and spreading into the midwest states (Oklahoma, Texas), whereas IFLOWS are in the East Coast states. ALERT networks mainly serve counties or cities due to the wide state dimensions, whereas IFLOWS networks serve a state or neighboring states.

ALERT also employs the same equipment as IFLOWS for the radio reporting rain gage, data collection or backbone communications, voice communications, etc. However, ALERT gages are also being routinely equipped with additional analog measurement sensors (wind speed or direction, solar radiation, temperature, relative humidity, barometric pressure). The analog sensor data is encoded and transmitted along with the rainfall data on preset time intervals. The sensor data can be sent regularly or only if it varies beyond certain preset percentages.

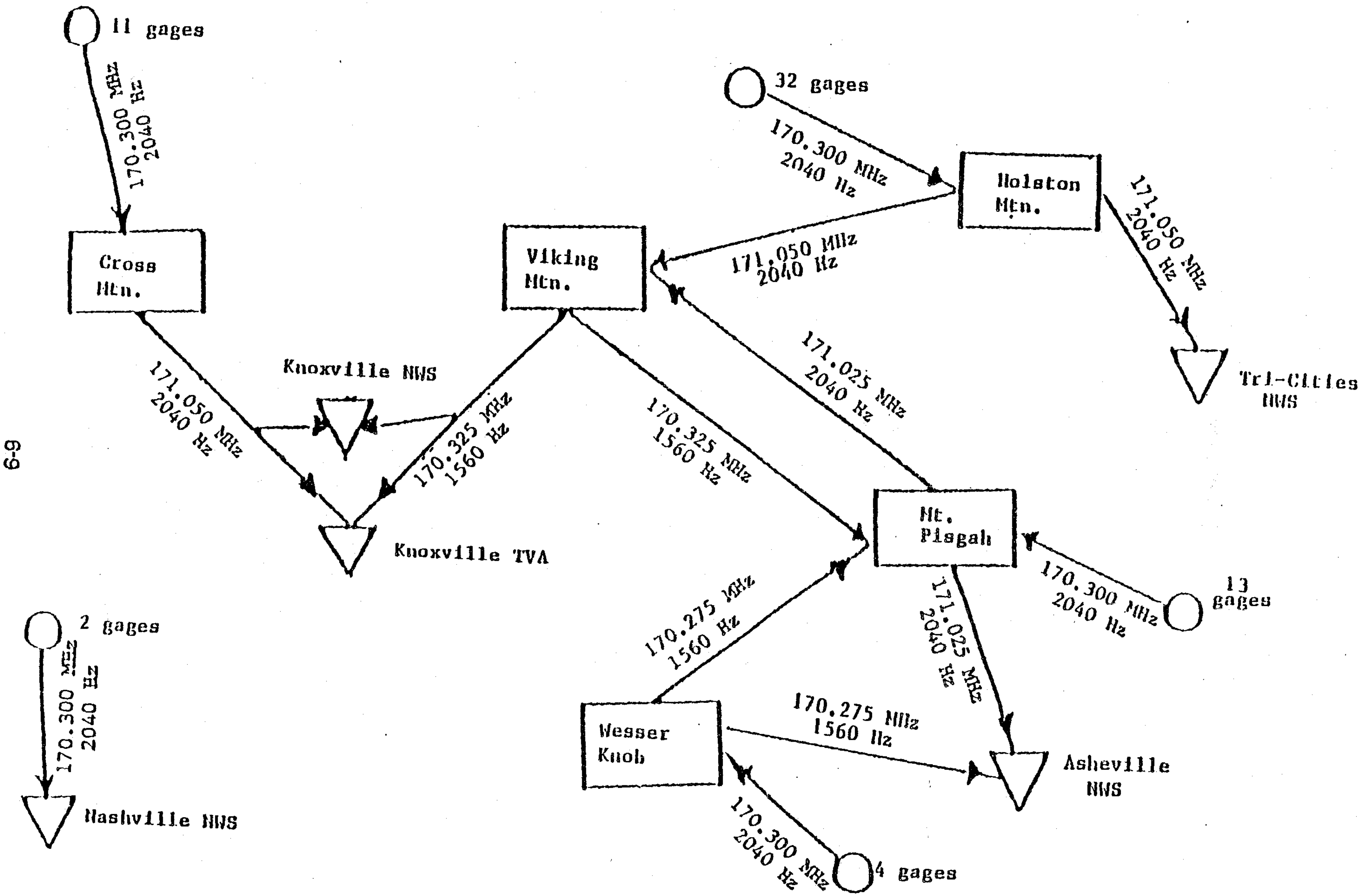


Figure 6-5. Tennessee/North Carolina IFLOWS Communications Network

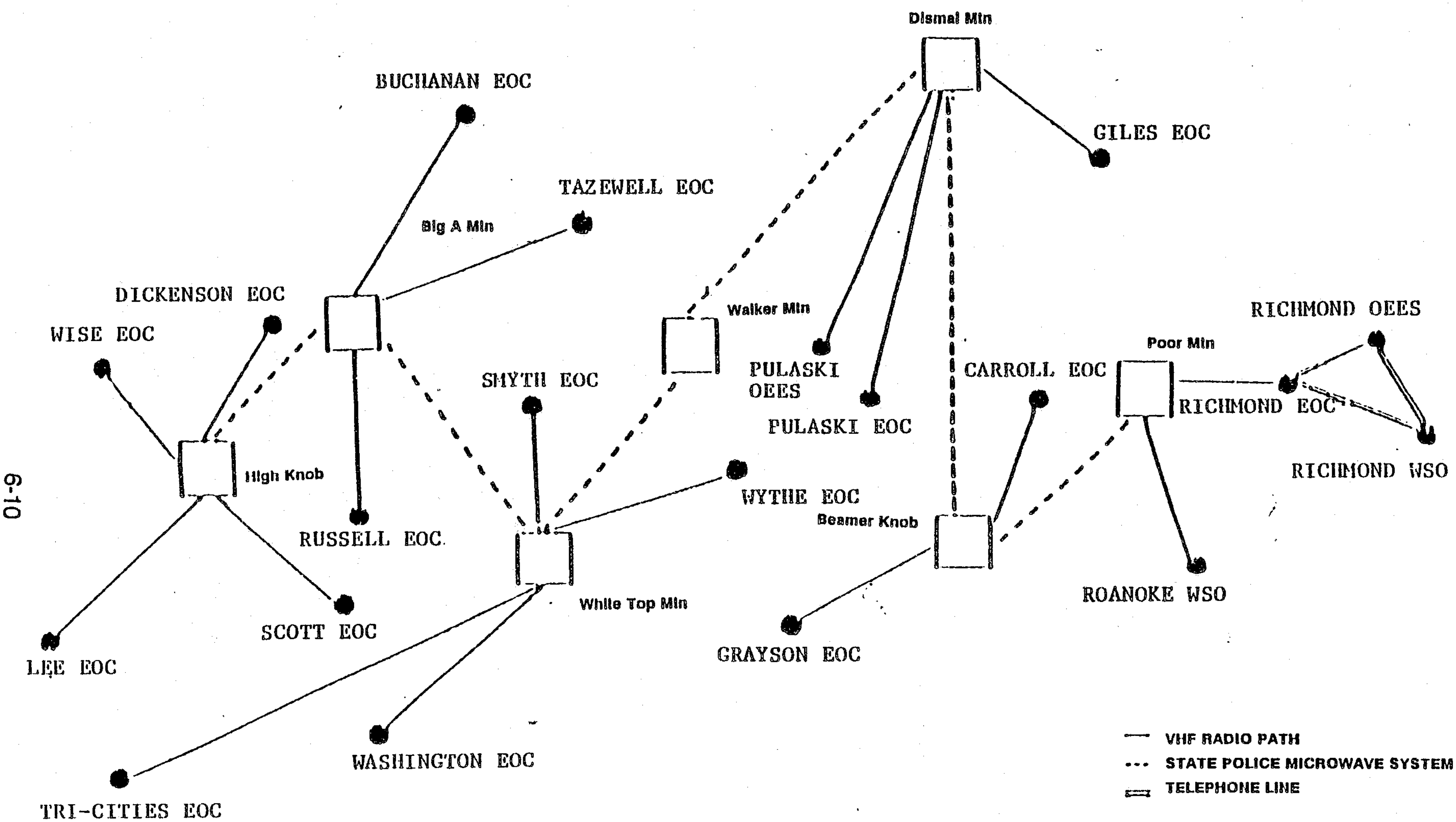


Figure 6-6. Virginia IFLOWS Communications Links

A complete Radio Reporting Weather Station (RRWS) that includes all sensors is illustrated in Figure 6-7. The manufacturers estimate that about 10% of the equipment made available to users represents the RRWS complete package. A typical RRRG alone with frequency synthesis capability to transmit at any of the hydrologic channels costs about $3000 (three thousand dollars), and a single extra sensor cost varies from $200 to $500 (two hundred to five hundred dollars) depending on the measured parameter. The extra sensors are included by the manufacturer as requested by the network users, and are expected to be also employed in the IFLOWS networks eventually.

A Radio Reporting Stream Gage (RRSG) is also manufactured and employed for remote stream measurements and data transmission. A sensor mechanism and shaft encoder located in a stilling well monitors the water level and provides preset incremental measurements. The transmitter is included inside the well housing, or is located in a separate standpipe tower similar to the RRRG or RRWS structure but connected by cable to the shaft encoder inside the well, as illustrated in Figures 6-8 and 6-9.

The same manufacturers also make store-and-forward VHF or UHF radio repeaters to extend the line-of-sight distance between the sensor stations and the operation centers, by locating the repeaters in elevated terrain, mountains, towers, buildings, etc. The received signal is stored momentarily and retransmitted at the same frequency with only one antenna required, and the repeater can be preset to respond only to certain sensor transmission codes so as to avoid noise and interference responses. The repeaters can also be installed in the standpipe tower structures already discussed.

The same manufacturers also make compatible base stations with hardware and software to process the transmissions received from multiple remote sensors or repeaters. The hardware includes receiver/decoder units that can operate at 300 or 1200 baud concurrently to support mixed data transmissions. The software supports MS/DOS compatible computers and text/graphics color displays, with multitasking capability to perform data collection and data processing concurrently. Text processing includes menu options, data archiving and display, summary reports, automatic alarm trigger, etc., and the graphics displayed can represent map information, multiple sensor data, measured parameter fluctuations, hydrograph curves, forecast models, etc.

Another distinction between ALERT and IFLOWS operations is that ALERT uses multiple hydro channels (two or three) in a network for data collection. IFLOWS uses the same hydro channel for data collection in its typical networks, though multiple channels are used for data backbone communications. ALERT has too many RRPG transmitters operating simultaneously and cannot meet throughput requirements with a single channel for data collection.

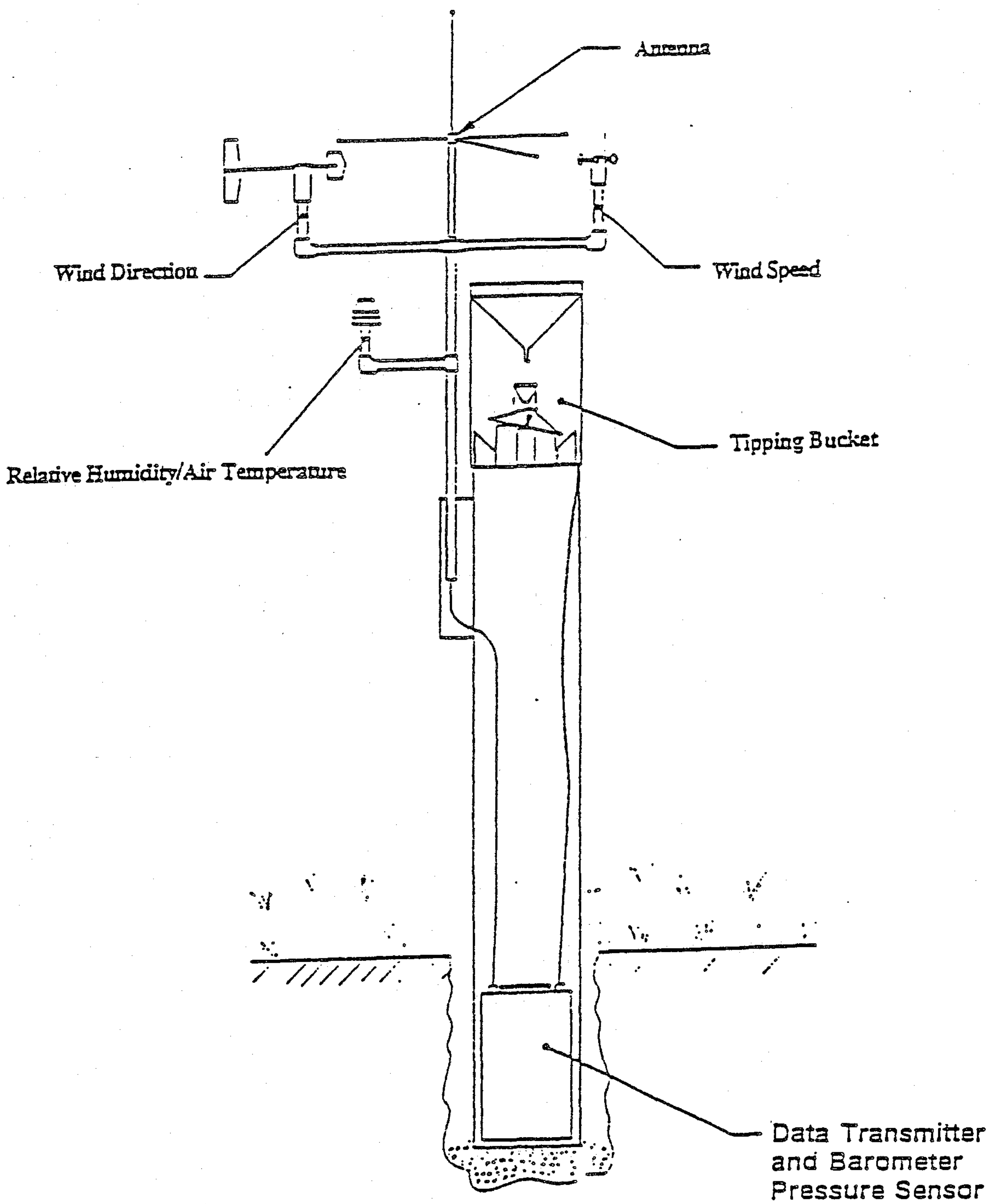


Figure 6-7. Radio reporting weather station

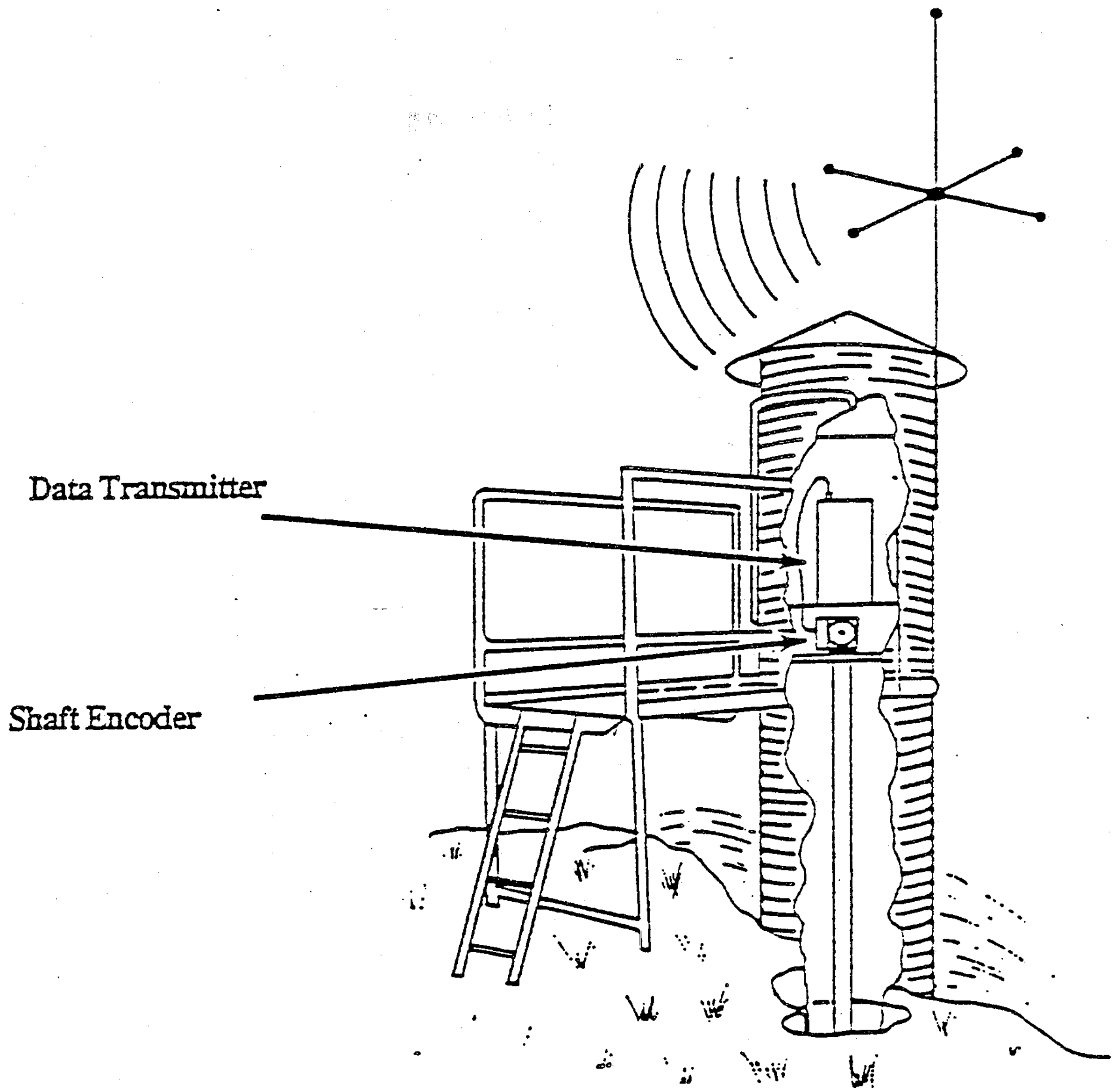


Figure 6-8. Radio reporting stream gage with internal transmitter

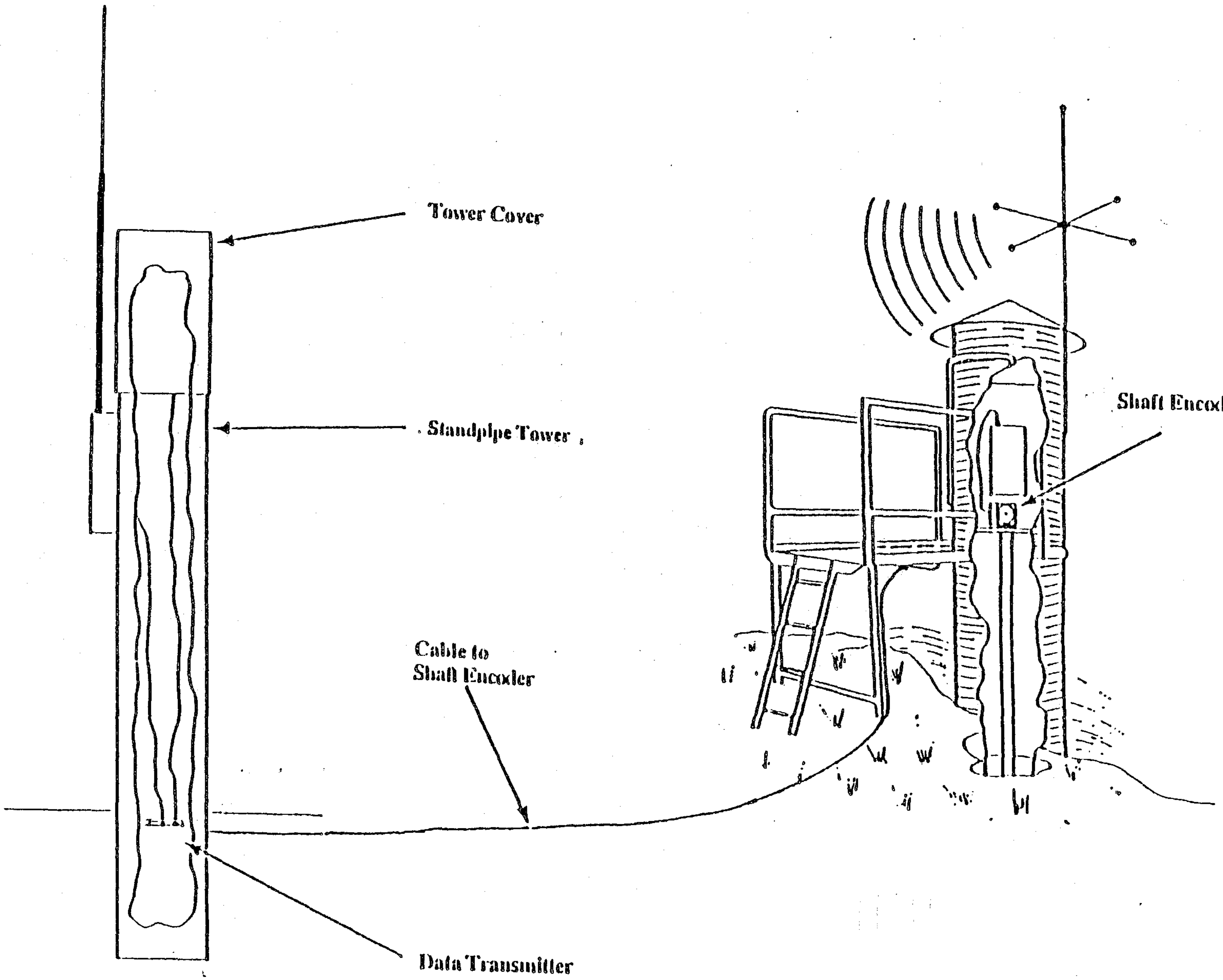


Figure 6-9. Radio reporting stream gage with external transmitter

The same throughput limitation has motivated the potential extension from 300 to 1200 baud for data collection, and all ALERT RRPGs are now being built with a switch to handle both modes. Both ALERT and IFLOWS are expected to support 1200-baud data collection as a standard operation in the near future, particularly considering that this rate is supported by the data backbone communications.

The backbone dissemination in ALERT apparently relies more on telephone lines than in microwave links as IFLOWS does. Again, there are no universal link procedures for data backbone communications, which adapt according to the community needs and resources. ALERT does have a standards committee that meets quarterly and has special conferences in California. They set the data format and operation standards, support network linkages and user groups, disseminate information on developments, etc.

SECTION 7

HYDROLOGIC EMISSION BANDWIDTH ANALYSIS

F2E AND F3E 16 kHz EMISSION CHARACTERISTICS

The majority of the hydrologic stations exhibit a 16 kHz emission bandwidth associated with both the F2D digital data and F3E analog voice emissions. The analog voice baseband consists of 3 kHz single-channel speech that is applied to an FM carrier to generate the F3E emission. A 5 kHz peak frequency deviation is employed in present systems, which results in an emission bandwidth of 16 kHz based on Carson's Rule.

The F2D emission generation consists of an FSK/FM modulation process as illustrated in Figure 7-1. The digital information data is used to shift the frequency of an audio subcarrier between two tone values according to the binary data state. The FSK audio baseband thus obtained is then applied as modulation to an FM carrier to generate the F2D emission. This FSK/FM signaling approach represents two cascaded bandwidth expansion processes relative to the original information bandwidth.

The digital information rate is R = 300 bps or 1200 bps, which also corresponds to the first spectral lobe of its power spectrum when NRZ rectangular pulses are used for the binary symbols. This first spectral lobe contains 90% of the power, so that the information data rate may be identified as the information bandwidth. The FSK subcarrier modulation creates a new and wider baseband prior to the FM carrier modulation, with a new top baseband frequency (F_m) replacing the information bandwidth (R) before modulating the carrier.

The FSK modulation parameters can be specified as the binary audio frequency states (F_1,F_2), or as the subcarrier center frequency $F_{sc} = 0.5\,(F_1 + F_2)$ and the subcarrier frequency deviation $D_{sc} = 0.5\,|F_1 - F_2|$. The new baseband obtained is centered at F_{sc} and has a certain bandwidth B_{sc} determined by the FSK modulation parameters. The NTIA Manual, Annex J, has a simple formula to estimate the bandwidth (B_{sc}) needed to preserve 99% of the FSK signal power as follows:

$$B_{sc} = \begin{cases} 3.88\ D_{sc} + 0.27\ R, & \text{if } 0.03 < \dfrac{2D_{sc}}{R} \le 1.0 \\[2ex] 2.4\ D_{sc} + 1.0\ R, & \text{if } 1.0 \le \dfrac{2D_{sc}}{R} < 20 \end{cases}$$

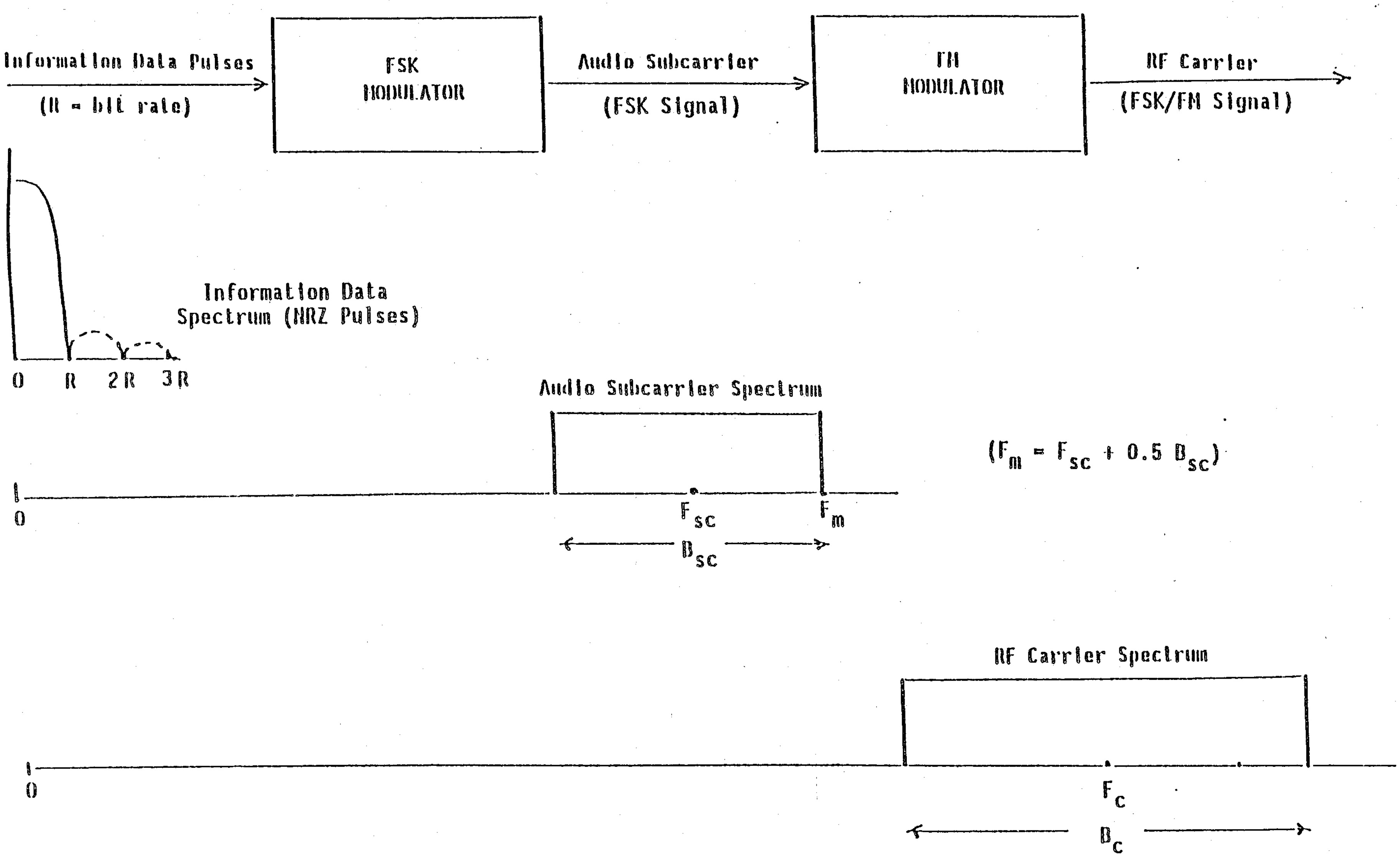


Figure 7-1. F2D emission spectrum generation

The top baseband modulating frequency on the FM carrier is obtained from the FSK signal bandwidth as $F_m = F_{sc} + 0.5\ B_{sc} = 0.5\ (F_1 + F_2 + B_{sc})$. The FM carrier bandwidth (B_c) can then be estimated for a given peak carrier deviation (D_c) as $B_c = 2\ (D_c + F_m)$ based on Carson's Rule. The bandwidth expansion factor of the total FSK/FM process relative to the original information bandwidth is given by $B_c/R = (B_c/F_m) \cdot (F_m/R)$, as the product of the two partial expansion factors due to the FM and FSK modulation processes in cascade.

The modulation specifications of existing hydrologic systems are employed in TABLE 7-1 to derive the FSK subcarrier baseband parameters (B_{sc},F_m), and the corresponding partial and total bandwidth expansion factors. The results obtained can be summarized as follows:

- The F2D emission bandwidth (B_c) is indeed about 16 kHz for both information data rates (R), even though the FSK subcarrier modulation parameters (F_{sc},D_{sc}) and FSK signal bandwidth (B_{sc}) are different.

- The top baseband frequency (F_m) of the FSK subcarrier signal approximates the 3 kHz occupancy of analog speech for 1200 bps data, and is only slightly lower for 300 bps data.

- The total bandwidth expansion factor (B_c/R) of the FSK/FM process is about 50 for 300 bps and 13 for 1200 bps, in order to produce the 16 kHz F2D emission bandwidth. The main distinction is in the FSK baseband expansion, with a factor (F_m/R) of 7.6 for 300 bps and 2.4 for 1200 bps, in order to approximate a 3 kHz baseband. The FM expansion factor (B_c/F_m) is similar for both rates, since the top baseband frequency (F_m) of the FSK subcarrier signal is similar.

Measurements of the F2D emission spectrum are shown in Figure 7-2, as provided by the equipment manufacturers. The top picture corresponds to a VHF remote-sensor station transmitter, and the bottom picture to a VHF repeater station transmitter. Both transmitters represent equipment presently employed in existing hydrologic systems and operations.

BANDWIDTH CONSERVATION ALTERNATIVES

The modulation method employed in the majority of the hydrologic emissions has been shown to consist of accepting (for voice) or creating (for data) an audio baseband (analog voice channel, digital FSK data subcarrier), which is then applied as frequency modulation to generate the 16 kHz F3E (FM voice) or F2D (FSK/FM data) emissions. The FSK subcarrier baseband generates a lowpass occupancy similar to the voice channel (2.3 kHz for 300 bps and 2.8 kHz for 1200 bps versus 3 kHz for speech) prior to the FM carrier modulation.

TABLE 7-1

F2D MODULATION EXAMPLES

FSK AUDIO-SUBCARRIER GENERATION		
Information Data Rate (R)	300 bps	1200 bps
Binary Audio Frequencies (F_1,F_2)	1920,2133 Hz	1200,2200 Hz
Subcarrier Center Frequency (F_{sc})	2026.5 Hz	1700 Hz
Subcarrier Peak Deviation (D_{sc})	106.5 Hz	500 Hz
Audio Subcarrier Bandwidth (B_{sc})	492 Hz	2254 Hz
FM RF-CARRIER GENERATION		
Carrier Modulating Frequency (F_m)	2272.5 Hz	2827 Hz
Carrier Peak Deviation (D_c)	5000 Hz	5000 Hz
RF Carrier Bandwidth (B_c)	14545 Hz	15654 Hz
BANDWIDTH EXPANSION FACTORS		
FSK Baseband Expansion Factor (F_m/R)	7.6	2.4
FM Bandwidth Expansion Factor (B_c/F_m)	6.4	5.5
FSK/FM Bandwidth Expansion Factor (B_c/R)	48.6	13.2

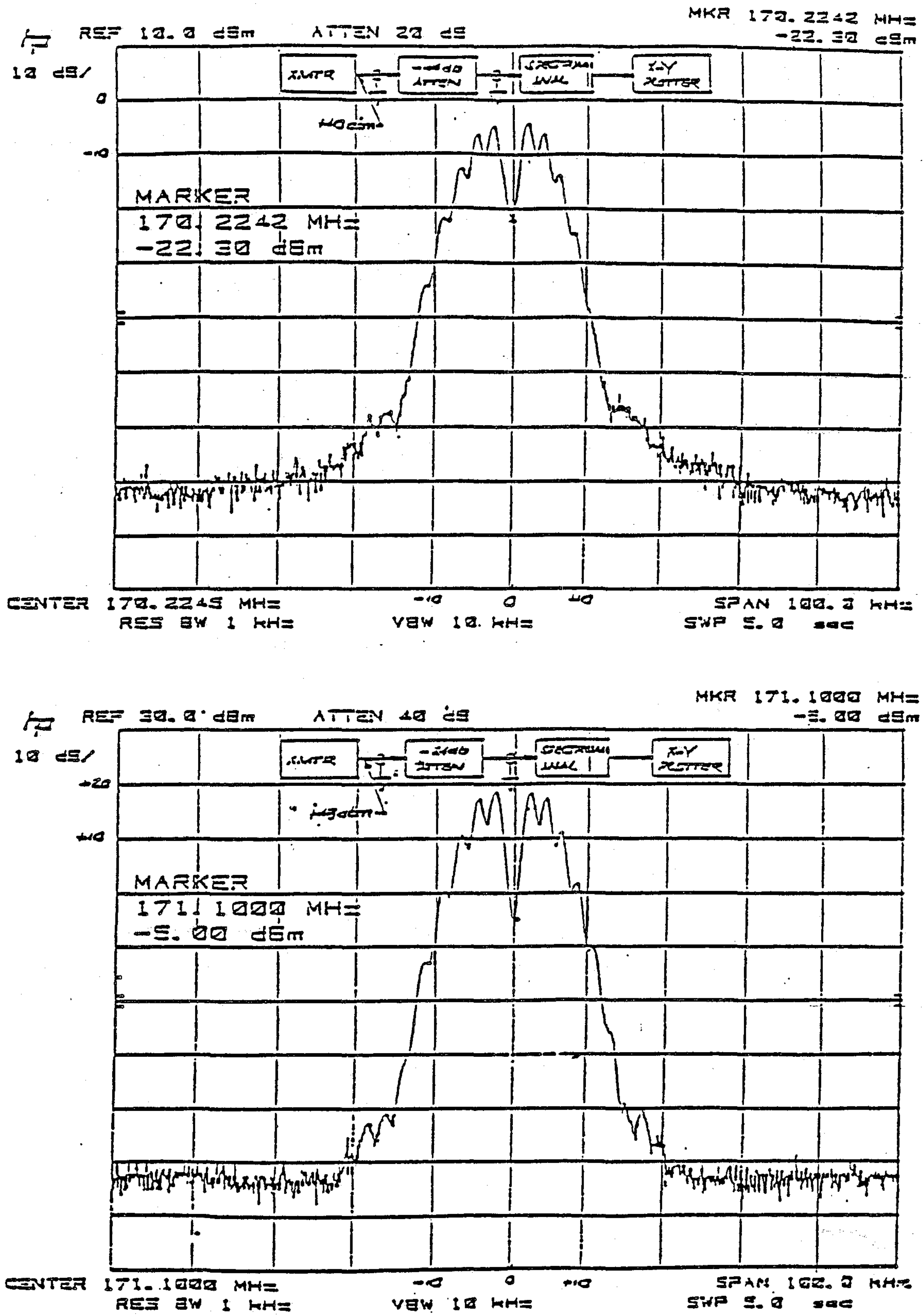


Figure 7-2. ALERT transmitter emission spectrum: Remote Sensor Station (Top), Repeater Station (Bottom)

The discussion that follows addresses potential modifications to these modulation processes towards reducing the emission bandwidths while supporting the same information rate (3 kHz speech, 300/1200 bps data). There are two basic generic approaches that should be distinguished due to their distinct implementation and economic implications, as follows

- Modify only the carrier modulation process while keeping the present audio basebands intact, so that the FSK data subcarrier with its speech-like occupancy is preserved.

- Modify the carrier and/or subcarrier modulation processes, such that the preservation of the existing FSK data subcarrier or its speech-like occupancy is not required.

The first approach is only concerned with reducing the bandwidth expansion factor relative to the present audio basebands, which is of the order of 5 to 7 with the existing FM carrier modulation. The FSK baseband expansion relative to the information data rate would be preserved in the first approach, but could be reduced or avoided by the second approach (e.g., eliminated if direct-carrier modulation is used for the data emissions).

A motivation for maintaining the FSK audio subcarrier generation in the hydrologic data emissions is that the baseband modems supporting the data communications between the operation centers and nodes are presently designed to automatically handle the FSK audio signal and perform RS-232C standard conversions for data processing and computer interfacing. A departure from the FSK audio subcarrier approach would imply new modem implementations to a massive extent, and perhaps new technology development based on the new modulation to be supported.

A motivation for maintaining the 300/1200 bps data transformation into a wider audio baseband with speech-like occupancy is the present capability of using common transmit and receive equipment to handle the voice or data emissions without distinction. If a narrower baseband occupancy and emission bandwidth is provided with a new data signal, then not only new station equipment will be required, but distinct equipment will have to be dedicated to voice versus data support.

Such need for dual equipment would apply to the backbone links of the hydrologic networks, which usually handle both voice and data emissions, as indicated by the dual station classes and emission designators in the GMF assignments. It would also restrict some data collection links if they have been (or will be) expanded to support voice besides data messages (e.g., emergency reports from human observers at remote sites), since new narrowband data equipment may not accommodate a voice baseband.

CARRIER MODULATION MODIFICATION WITH FSK SUBCARRIER PRESERVATION

The simplest approach with minimum impact is to reduce the FM carrier deviation, while preserving the analog voice channel and digital FSK subcarrier basebands. For example, a 2 to 3 kHz deviation yields a 10 to 12 kHz emission bandwidth for the 3 kHz speech baseband based on Carson's Rule. The digital FSK subcarrier basebands would result in emission bandwidths of 8.6 to 10.6 kHz for 300 bps, and 9.6 to 11.6 kHz for 1200 bps, with a 2 to 3 kHz FM carrier deviation.

The maximum bandwidth reduction while preserving the existing audio basebands is obtained by using SSB/AM instead of FM for the carrier modulation. The emission bandwidth would then be approximately 3 kHz for speech, 2.8 kHz for 1200 bps data, and 2.3 kHz for 300 bps data. A slight increase may occur depending on the spectral location of a pilot tone included in the SSB/AM signal structure. This pilot tone is a low-level signal employed to provide amplitude or frequency references and implement receiver processing improvements needed to circumvent some distortion limitations of SSB/AM relative to FM (W. Shelton, et al, NTIA Report 84-156).

For the analog voice emissions, the bandwidth expansion factor is about 1.0 for SSB/AM, and 3.3 to 4.0 for FM with 2 to 3 kHz carrier deviation, which should be compared to the 5.3 expansion factor that occurs with the present FM modulation parameters. For the digital data emissions with the FSK subcarrier preserved, the bandwidth expansion factors are summarized in TABLE 7-2 for these modulation alternatives, and should be compared to the expansion factors of 50 (for 300 bps) or 13 (for 1200 bps) that occur with the present FSK/FM modulation parameters.

The emission bandwidth conservation provided by these modulation alternatives is accompanied by a reduction in output performance; i.e., the output signal-to-noise power ratio (SNR) in the analog voice or digital subcarrier baseband demodulated. A reduction from the 5 kHz FM deviation presently employed conserves bandwidth but reduces output SNR; e.g., a 2 to 3 kHz deviation is an 8.0 to 4.4 dB reduction relative to 5 kHz deviation. The use of SSB/AM for maximum bandwidth conservation fully eliminates the FM improvement factor otherwise achieved in the output SNR performance, with the only processing gain being a companding effect.

The output SNR degradation will affect the speech quality and the data error rate, under equivalent operational conditions (i.e., same frequency band and link power budget). If such degradation results in an unacceptable performance, then an increased transmitter power, shorter links and more repeaters, or special baseband processing (e.g., speech companding, data error-correction coding) would be required while operating in the same band. For example, companded SSB/AM and 2.5 kHz deviation FM have been considered as VHF land-mobile

TABLE 7-2

EMISSION BANDWIDTH CONSERVATION ALTERNATIVES WITH FSK SUBCARRIER GENERATION PRESERVED

FM Carrier Generation Option	ACSB*		NBFM (D_c = 2 kHz)		NBFM (D_c = 3 kHz)	
Baseband Information Data Rate (R, bps)	300	1200	300	1200	300	1200
FSK Top Baseband Frequency (F_m, Hz)	2272.5	2827	2272.5	2827	2272.5	2827
Emission Bandwidth (B_c, Hz)	2272.5	2827	8545	9654	10545	11654
Subcarrier Baseband Expansion Factor (F_m/R)	7.6	2.4	7.6	2.4	7.6	2.4
Carrier Modulation Expansion Factor (B_c/F_m)	1.0	1.0	3.8	3.4	4.6	4.1
Total Bandwidth Expansion Factor (B_c/R)	7.6	2.4	28.5	8.0	35.2	9.7

*ACSB bandwidth could be larger depending on pilot tone location in signal structure.

alternatives to conventional 5 kHz deviation FM, and shown to compromise service quality only at the communication range limits (weak signal conditions degraded speech intelligibility), with SSB/AM being more affected than 2.5 kHz FM relative to 5 kHz FM (W. Shelton, et al, NTIA Report 84-156).

DIRECT-CARRIER MODULATION BY DATA

The existing FSK data subcarrier already features a baseband expansion factor of only 2.4 at 1200 bps, which can become the data rate standard in the near future. This limits the emission bandwidth saving potential via baseband occupancy reduction, while maintaining a simple digital subcarrier modulation. For example, binary PSK with 90% power preserved would still represent a baseband expansion factor of about 2.0, and would need quaternary PSK for a 1.0 factor with 90% power preserved (or high-alphabet QAM for factors below unity) to get sizeable occupancy savings relative to the existing FSK subcarrier baseband.

There still would remain the bandwidth expansion factor due to a carrier modulation process. It is evident that if the preservation of the data subcarrier baseband with speech-like occupancy is negotiable, the logical direction towards bandwidth conservation is to eliminate the subcarrier and rely on direct-carrier modulation by the data. And it should be well accepted that this would have strong implementation and economic repercussions due to the new transmit, receive, and modem equipment that will be needed as replacement to a massive extent.

The use of analog direct-carrier modulation by data pulses has been essentially limited to FSK in practice, with conventional discriminators employed at the receiver for the pulse train demodulation before the digital state decisions. The emission spectrum when using rectangular pulses is similar to that obtained in digital FSK, and there are other digital direct-carrier modulations capable of producing a narrower emission bandwidth, while still maintaining the incoherent detection capability and providing comparable error performance (e.g., DPSK, MSK).

The use of SSB/AM for direct-carrier modulation by data pulses would provide maximum emission bandwidth conservation, but this method is severely hindered by the large peak envelope excursions in the modulated signal. Such envelope peaks would have to be accommodated by the transmitter peak-power specifications to avoid saturation (clipping distortion), and the SSB/AM peaks that occur with pulse modulation are very high compared to speech modulation. Hence, SSB/AM has been found to be not suitable for data transmission, while remaining useful for voice communications.

With reference to digital direct-carrier modulation methods, the simpler approach is binary PSK which requires an emission bandwidth of about twice the bit rate with 90% power preserved, e.g., 600 Hz for 300 bps and 2400 Hz for 1200 bps. The receiver could rely on differential detection to avoid the more complex coherent detection with a tracking loop required, though sacrificing a 3 dB performance margin in the exchange.

Any further bandwidth reduction must be provided by using a higher digital alphabet with the corresponding equipment complexity and error performance compromises (e.g., more signal power is needed for the same error rate as the alphabet size increases). For example, quaternary PSK requires an emission bandwidth equal to the bit rate with 90% power preserved, and higher PSK or QAM alphabets can support smaller bandwidths by a factor of $\log_2 M$, where M is the alphabet size (e.g., $\log_2 M = 6$ for 64 QAM).

The basic distinction in PSK versus QAM with higher alphabets is in the error rate performance and the equipment processing requirements, since they essentially support the same emission bandwidth for a given alphabet size. QAM has more digital detection immunity than PSK for the same alphabet due to the joint amplitude and phase discrimination, but PSK is a constant-envelope signal (unlike QAM) plus it does not necessarily require coherent detection (unlike QAM).

In any case, extensive equipment modification with more complexity would be required with higher digital modulation. Even binary PSK with its moderate bandwidth conservation would now be an expensive alternative, given the amount of existing FSK/FM hydrologic emissions and FSK baseband interface modems. The possible proliferation of higher digital modulation in the future could make such options more affordable, but there would still then remain the need for dual equipment dedication to handle data and voice transmissions differently.

BANDWIDTH ANALYSIS AND CONSERVATION SUMMARY

The 16 kHz bandwidth predominantly assigned for the F2D and F3E hydrologic emissions is the necessary bandwidth for the modulation methods and parameter specifications employed. The 300/1200 bps data conversion to an FSK audio subcarrier baseband essentially matches the 3 kHz voice baseband occupancy, and permits common station equipment employed for data/voice communications. It also permits standard FSK modem compatibility for automated data processing and computer interfacing in the hydrologic networks.

The use of analog narrowband technology can maintain these features while also providing narrowband operation and bandwidth conservation. Amplitude compandored single-sideband (ACSB) and narrowband frequency modulation (NBFM) represent this analog narrowband technology. The NBFM approach has minimum impact in equipment modification, since only a reduction in the FM carrier deviation value from 5 kHz to about 3 kHz is required. Also, NBFM has shown more performance degradation immunity than ACSB in recent experimental tests.

NBFM commercial equipment is not currently marketed in the United States for the VHF or UHF band, though it is readily available in Europe for these bands. This suggests that a five year period could suffice for NBFM availability, particularly since the development of a 12.5 kHz channeling plan for the overall VHF band is presently under consideration to resolve sharing and congestion concerns. Also, 25 kHz FM and 12.5 kHz NBFM commercial equipment is currently available in the United States for other higher frequency bands, as discussed in the next section.

The use of direct carrier modulation for the digital data emissions has more bandwidth conservation potential, but the preservation of the FSK audio baseband would be lost thus making all FSK audio modems obsolete and requiring massive modem replacement. There would also be new and more sophisticated transmitters and receivers required in the hydrologic stations to support the data collection or backbone communications, making this option very questionable from cost/complexity considerations at this stage.

SECTION 8

POTENTIAL BAND RELOCATION OF HYDROLOGIC CHANNELS

HYDROLOGIC CHANNEL RELOCATION CONSIDERATIONS

The 162-174 MHz (VHF) and 406.1-420 MHz (UHF) bands are mainly allocated to government Fixed and Mobile Services on a primary basis. The major exception (besides footnotes) is the 173.2-173.4 MHz portion, which is allocated to nongovernment Fixed (primary basis) and Land Mobile (secondary basis) Services. The 406.1-410 MHz band is also allocated to the government/nongovernment Radio Astronomy Service on a primary basis.

In particular, the VHF band has been cited as becoming congested due to proliferating land-mobile government operations, and the possibility of using an alternate frequency band for the Fixed Service has been proposed to alleviate the situation, (IRAC DOC. 26223/1). The majority of the hydrologic channel assignments represents hydrologic operations and corresponds to the Fixed Service, so that the potential relocation of hydrologic channels automatically becomes part of the issue.

The potential relocation of the VHF hydrologic channels offers two main options. One is to relocate them to the UHF band, where hydrologic technology and operation logistics is well established. Another is to relocate them to another band, in which case a purely Fixed Service band would be ideal. Such a band would exhibit no spectrum sharing concerns or complex coordination requirements to accommodate other services.

If the VHF hydrologic channels are to be relocated to a band other than the UHF band, then the potential relocation of the UHF hydrologic channels must also be considered. Otherwise, the natural trend for hydrologic users will be to relocate to the UHF band rather than to the new band available, since the equipment availability and operation logistics are well established in the UHF hydrologic channels.

It would be actually simpler to relocate the UHF hydrologic service to the VHF band than the reverse, since the UHF band has considerably less hydrologic assignments, and the VHF band has many more hydrologic plus interstitial channels in the hydro blocks. Moreover, the narrowband channeling plans currently being considered for the VHF band could be used to create any needed bandwidth support for the narrowband relocation of the UHF hydrologic service.

The 30-50 MHz band is another relocation alternative, since it was originally allocated along with the VHF and UHF bands in question for government Fixed and Mobile Service support. This band contains various noncontiguous slots where the hydrologic channels could be accommodated with current (25 kHz) or narrowband (12.5 kHz) channel bandwidths, but separated by gaps presently dedicated to nongovernment Land Mobile Service. Also, there are no specifically designated hydrologic channels in these slots, plus the system links would exhibit propagation reliability uncertainties, besides the mutual interference potential between hydrologic (fixed) and mobile stations.

On this basis, the following potential relocation cases will be addressed in the discussion that follows:

- VHF hydrologic service accommodation in the UHF band
- UHF hydrologic service accommodation in the VHF band
- VHF and UHF hydrolgic service accommodation in purely Fixed Service bands

VHF HYDROLOGIC CHANNEL ACCOMMODATION IN UHF BAND

The accommodation bandwidth needed by the 20 hydrologic plus 1 quasi-hydrologic VHF channels is 525 kHz with a 25 kHz channel bandwidth, or 262.5 kHz with a 12.5 kHz channel bandwidth. The UHF hydrologic bandwidth span currently available is 225 kHz, as provided by the eight hydrologic plus one quasi-hydrologic channels. Hence, VHF accommodation in the UHF band without a reduction in the number of channels is not possible, even when considering a 12.5 kHz UHF hydrologic split-channel operation (i.e., 18 UHF narrowband channels would have to accommodate 21 VHF plus 9 UHF narrowband channels).

The accommodation of more hydrologic channels in the UHF band can be accomplished by dedicating the 25 kHz gaps between the current neighboring hydrologic channels to hydrologic operations (i.e., the gaps would become hydrologic channels). However, there are only four such gaps, which represents 100 kHz in additional bandwidth capable of supporting only four more 25 kHz channels or eight more 12.5 kHz channels. Moreover, these gaps presently have mobile and land-mobile assignments which would have to be grandfathered, so that the new UHF hydrologic channels would not be fully protected for awhile.

UHF HYDROLOGIC CHANNEL ACCOMMODATION IN VHF BAND

The accommodation bandwidth needed by the eight hydrologic plus one quasi-hydrologic UHF channels is 225 kHz with a 25 kHz channel bandwidth, or 112.5 kHz with a 12.5 kHz channel bandwidth. The VHF hydrologic bandwidth span currently available is 525 kHz, as provided by the 21 hydrologic plus 1 quasi-hydrologic channels. There are various relocation possibilities to be considered as follows.

A direct absorption of the 9 current UHF channels into the 21 current VHF channels may not be desirable since VHF hydrologic user congestion could be created. If the 25 kHz channel bandwidths are to be preserved, it is preferable to relocate the UHF channels to the 16 VHF interstitial channels inside the four hydro blocks, which are allowed to support emissions with 16 kHz or less necessary bandwidth. However, potential interference between the regular and interstitial hydrologic channels can still limit the user capacity that can be accommodated. Also, the spectral congestion relative to other services in the band would remain unresolved.

The best solution for the VHF band itself consists of using 12.5 kHz hydrologic channel bandwidths, which can be provided with narrowband technology as previously discussed. The 21 VHF hydrologic channels would need only 262.5 kHz of the 525 kHz currently provided, and some of the 262.5 kHz bandwidth liberated can be used to support the nine UHF hydrologic channels, which would be also narrowbanded besides relocated. The 112.5 kHz bandwidth needed for the narrowband UHF hydrologic accommodation would still leave 150 kHz of total bandwidth available after the narrowband relocation.

This 150 kHz total bandwidth would still be located inside the VHF hydro blocks, which currently contain all the wireless microphone channels. If this 150 kHz bandwidth is used to support mobile or land-mobile operations, the mutual interference potential with the wireless microphone operations would be enhanced. It is preferable to dedicate the 150 kHz to fixed station operations only, and grandfather some of the Fixed Service out of other VHF or UHF band portions then left open for Mobile or Land Mobile Service exclusively. This would help alleviate congestion, and the hydrologic community would also profit since the Fixed Service dedication can be used for hydrologic stations as well.

HYDROLOGIC CHANNEL ACCOMMODATION IN PURELY FIXED BANDS

The National Table of Frequency Allocations of the NTIA Manual was investigated for purely Fixed Service bands as potential alternate bands for the hydrologic channels. A list of these bands with their corresponding bandwidth span is shown in TABLE 8-1, The top group consists of bands that are allocated to government and nongovernment on a primary basis. The bottom group consists of bands that are allocated only to nongovernment on a primary basis, and any government use of these bands is specified by footnotes as summarized in TABLE 8-2.

A 525 kHz bandwidth is needed to accommodate the VHF hydrologic channels while maintaining their 25 kHz bandwidth allocation. There are four bands in the top group of TABLE

TABLE 8-1

ALTERNATE FIXED SERVICE FREQUENCY BANDS

Frequency Band (MHz)	Bandwidth Span	Allocation	Footnotes
5.005-5.060	55 kHz	G,NG	
9.040-9.500	460 kHz	G,NG	
9.900-9.995	95 kHz	G,NG	
11.400-11.650	250 kHz	G,NG	
12.050-12.230	180 kHz	G,NG	
15.600-16.360	760 kHz	G,NG	
17.410-17.550	140 kHz	G,NG	
18.030-18.068	38 kHz	G,NG	
18.900-19.680	780 kHz	G,NG	
19.800-19.990	190 kHz	G,NG	
21.850-21.924	74 kHz	G,NG	
22.855-23.000	145 kHz	G,NG	
932.0-935.0	3 MHz	G,NG	US215, US268 NG120
941.0-944.0	3 MHz	G,NG	US268,US301,US302 NG64,NG120
928.0-929.0[a]	1000 MHz	NG	US116,US215,US268 NG120
944.0-960[b]	16 MHz	NG	NG64,NG120
1850.0-1990.0[b]	140 MHz	NG	
2110.0-2200[a]	90 MHz	NG	US111,US252 NG23

[a]Allocated to government via footnotes.
[b]Not allocated to government.

TABLE 8-2
(page 1 of 2)

FOOTNOTES TO THE FIXED SERVICE FREQUENCY BANDS

Government (G) Footnote

G2-----In the bands 216-225, 420-450 (except as provided by US217), 890-902, 928-942, 1300-1400, 2300-2450, 2700-2900, 5650-5925, and 9000-9200 MHz, the Government radiolocation is limited to the military services.

US111--In the band 1990-2120 MHz, Government space research earth stations may be authorized to use specific frequencies at specific locations for earth-to-space transmissions. Such authorizations shall be secondary to non-Government use of this band and subject to such other conditions as may be applied on a case-by-case basis.
Corpus Christi, Tex., 27° 39′ N 097° 23′ W.
Fairbanks, Alaska, 64° 59′ N 147° 53′ W.
Goldstone, Calif., 35° 18′ N 116° 54′ W.
Greenbelt, Md., 39° 00′ N 076° 50′ W.
Guam, Mariana Is., 13° 19′ N 144° 44′ E.
Kauai, Hawaii, 22° 08′ N 159° 40′ W.
Merritt Is., Fla., 28° 29′ N 080° 35′ W.
Rosman, N.C., 35° 12′ N 082° 52′ W.

US116--In the bands 890-902 MHz, 928-932 MHz, and 935-941 MHz, no new assignments are to be made to Government radio stations after July 10, 1970, except, on a case-by-case basis, to experimental stations and to additional stations of existing networks in Alaska. Government assignments existing prior to July 10, 1970 to stations in Alaska may be continued. All other existing Government assignments shall be on a secondary basis to stations in the non-Government land mobile service and shall be subject to adjustment or removal from the bands 890-902 MHz, 928-932 MHz, and 935-941 MHz, at the request of the FCC.

US215--Emissions from microwave ovens manufactured on and after January 1, 1980, for operation on the frequency 915 MHz must be confined within the band 902-928 MHz. Emissions from microwave ovens manufactured prior to January 1, 1980, for operation on the frequency 915 MHz must be confined within the band 902-940 MHz. Radiocommunications services operating within the band 928-940 MHz must accept any harmful interference that may be experienced from the operation of microwave ovens manufactured before January 1, 1980.

TABLE 8-2
(page 2 of 2)

US252--The bands 2110-2120 and 7145-7190 MHz, 34.2-34.7 GHz are also allocated for earth-to-space transmissions in the Space Research Service, limited to deep space communications at Goldstone, California.

US268--The bands 890-902 MHz and 928-942 MHz are also allocated to the radiolocation service for Government ship stations (off-shore ocean areas) on the condition that harmful interference is not caused to non-Government land mobile stations. The provisions of footnote US116 apply.

US301--Except as provided in US302, broadcast auxiliary stations licensed as of November 21, 1984, to operate in the band 942-944 MHz may continue to operate on a co-equal primary basis to other stations and services operating in the band in accordance with the Table of Frequency Allocations.

Non-Government (NG) Footnotes

US302--The band 942-944 MHz in Puerto Rico is allocated as an alternative allocation to the fixed service for broadcast auxiliary stations only.

NG23---Frequencies in the band 2100-2200 MHz may also be assigned to stations in the international fixed public radio service located south of 25°30′ north latitude in the State of Florida and in U.S. Possessions in the Caribbean area, provided, however, no new assignments in the band 2150-2162 MHz will be made to such stations after February 25, 1974.

NG64---Broadcast auxiliary stations licensed as of July 10, 1970, to operate in the frequency band 942-947 MHz may continue to so operate pending a decision as to their disposition through a future rule making procedure.

NG120--Frequencies in the 928-960 MHz band may be assigned for multiple address systems and mobile operations on a primary basis as specified in part 94.

8-1 that could potentially support this requirement (15.6-16.36 MHz, 18.9-19.68 MHz, 932-935 MHz, 941-944 MHz). The possible relocation while also narrowbanding the VHF hydrologic channels should be considered as well. The use of 12.5 kHz hydrologic channels would require only a 262.5 kHz total bandwidth, and one more frequency band (9.04-9.5 MHz) in the top group of TABLE 8-1 is added as a potential candidate.

If the eight hydrologic and one quasi-hydrologic UHF channels are also to be relocated, then an additional 225 kHz (25 kHz channels) or 112.5 kHz (12.5 kHz channels) is needed. The new totals of 750 MHz (25 kHz channels) or 375 kHz (12.5 kHz channels) can still be accommodated by the aforesaid bands for their respective cases, though some of the lower frequency bands would need most of their span and other services could be compromised. The lower frequency bands would also imply large antennas and propagation uncertainties, besides limited growth capacity.

The 932-935 MHz and 941-944 MHz bands do not have such limitations, plus they have been recently reserved for Fixed Service, and they are essentially unpopulated at present since they were a part of a nongovernment land-mobile reserve band. In particular, the 932-932.5 MHz and 941-941.5 MHz portions of these bands have been selected to support single-channel, point-to-multipoint links, which is compatible with the hydrologic operations and network configurations. There is only one assignment in Alaska and at the 941 MHz edge as of August 10, 1989, for these two subbands.

Each of these two subbands (932-932.5 MHz, 941-941.5 MHz) provides a 500 kHz bandwidth span that could accommodate the 750 kHz jointly (25 kHz channels) or the 375 kHz individually (12.5 kHz channels). However, the hydrologic users would not have exclusively dedicated channels since the band is shared, though the hydrologic operations would still be a primary protected service once assigned. The use of these subbands is expected to proliferate rapidly, so any hydrologic relocation would have to occur as soon as possible. Otherwise, there is no guarantee that the hydrologic bandwidth required will be made available, since there are no designated (existing or planned) hydrologic channels in these bands.

Some FM microwave station equipment for point-to-multipoint links in this band is already being marketed with FCC-type approval to support either 25 kHz channels (5 kHz FM deviation) or 12.5 kHz channels (3 kHz FM deviation). The necessary bandwidth and emission designators supported include 16 kHz for F2D emissions and 20 kHz for F3E emissions with a 25 kHz channel bandwidth, as well as 11 kHz for F2D emissions and 12.5 kHz for F3E emissions with a 12.5 kHz channel bandwidth. This implies that the FSK audio subcarrier baseband in the hydrologic emissions can be maintained, along with all the FSK audio modems presently employed in the hydrologic networks. In fact, the FSK audio modem support is one of the features being emphasized by the microwave equipment manufacturers.

BAND RELOCATION AND CHANNELING PLAN ASSESSMENT

The VHF to UHF hydrologic relocation is not desirable, since there are not enough UHF channels even if narrowband split-channels are considered to double the UHF user capacity. Conversely, the UHF to VHF hydrologic relocation is feasible, particularly if a 12.5 kHz narrowband channeling plan is established for the VHF band. The UHF hydrologic channels can be easily accommodated with 12.5 kHz VHF channel bandwidths, while still leaving 150 kHz extra total bandwidth available, and preserving the wireless microphone compatibility potential by judicious use of this 150 kHz bandwidth (e.g., fixed service dedication).

The relocation of the UHF hydrologic channels is also a good idea because the UHF hydrologic channeling plan is not very efficient by itself. The UHF hydrologic channels do not form contiguous blocks (unlike the VHF channels), with the exception of one block of three channels due to the UHF quasi-hydrologic channel location. This implies that the current UHF plan only has two interstitial channels inside one hydro block, in contrast to 16 total VHF interstitial channels inside the four hydro blocks.

Hence, the interstitial channels neighboring a hydrologic channel in the UHF band also have a nonhydrologic channel neighbor (with two exceptions), whereas there are 16 VHF interstitial channels with hydrologic channels as neighbors on both sides. The VHF hydro blocks essentially limit nonhydrologic interference potential to many interstitial channels via the contiguous channel arrangement, whereas the UHF hydrologic plan leaves all but two interstitial channels open to potential adjacent nonhydrologic interference. The lack of contiguous hydrologic channels is a major drawback for interstitial hydrologic operations in the UHF band.

If an overall 12.5 kHz channeling plan is to be implemented in the VHF band, the interstitial channels can become the new channels (center frequencies) being added. The current channels (center frequencies) would then also remain, and only their channel bandwidths would need to be halved. In particular, the VHF hydrologic channels would preserve their center frequencies in narrowband operation, and some of the current interstitial channels could be used to support the narrowband UHF hydrologic relocation. A total of 36 narrowband channels would be provided as shown in Figure 8-1, so that a surplus of narrowband channels would still be available inside the current hydro blocks, after the 21 VHF and 9 UHF narrowband hydrologic reaccommodation.

An alternative 12.5 kHz VHF channeling plan would have the current channels split in the middle to form two new center frequencies. The VHF hydrologic channels would then need to be shifted 6.25 kHz besides narrowbanded, and the other half of a split-channel could be used to support the narrowband UHF hydrologic relocation. A total of 40 narrowband channels would be provided as shown in Figure 8-2, so that a surplus of narrowband channels would still be available inside the hydro blocks, after the 21 VHF and 9 UHF narrowband hydrologic reaccommodation.

Both these VHF narrowband channeling plan options could still maintain most (Figure 8-1) or all (Figure 8-2) of the wireless microphone block umbrella by dedicating the surplus channels to All Government Agencies (AGA) for fixed service operations. The mitigation of the mutual interference potential between the wireless microphone and mobile/land-mobile operations in the band would then be preserved.

Finally, the joint VHF plus UHF relocation to another band has the 932-932.5 MHz and 941-941.5 MHz microwave bands as main candidates. They are new bands dedicated to only single-channel, point-to-multipoint, Fixed Service operations (IRAC Doc. 26332 (Agenda) and Second Order General Docket 82-243 (FCC), February 28, 1989) and there is equipment commercially available to support the F2D/F3E hydrologic emissions with either 25 kHz or 12.5 kHz channeling plans. However, a drawback is that they are for shared government/nongovernment support, so that there are no channels specifically provided for hydrologic operations unlike the current VHF and UHF bands. Moreover, the new band users are expected to proliferate rapidly, and the hydrologic support can be severely compromised unless hydrologic channels are specifically designated in these bands (which would require new regulations).

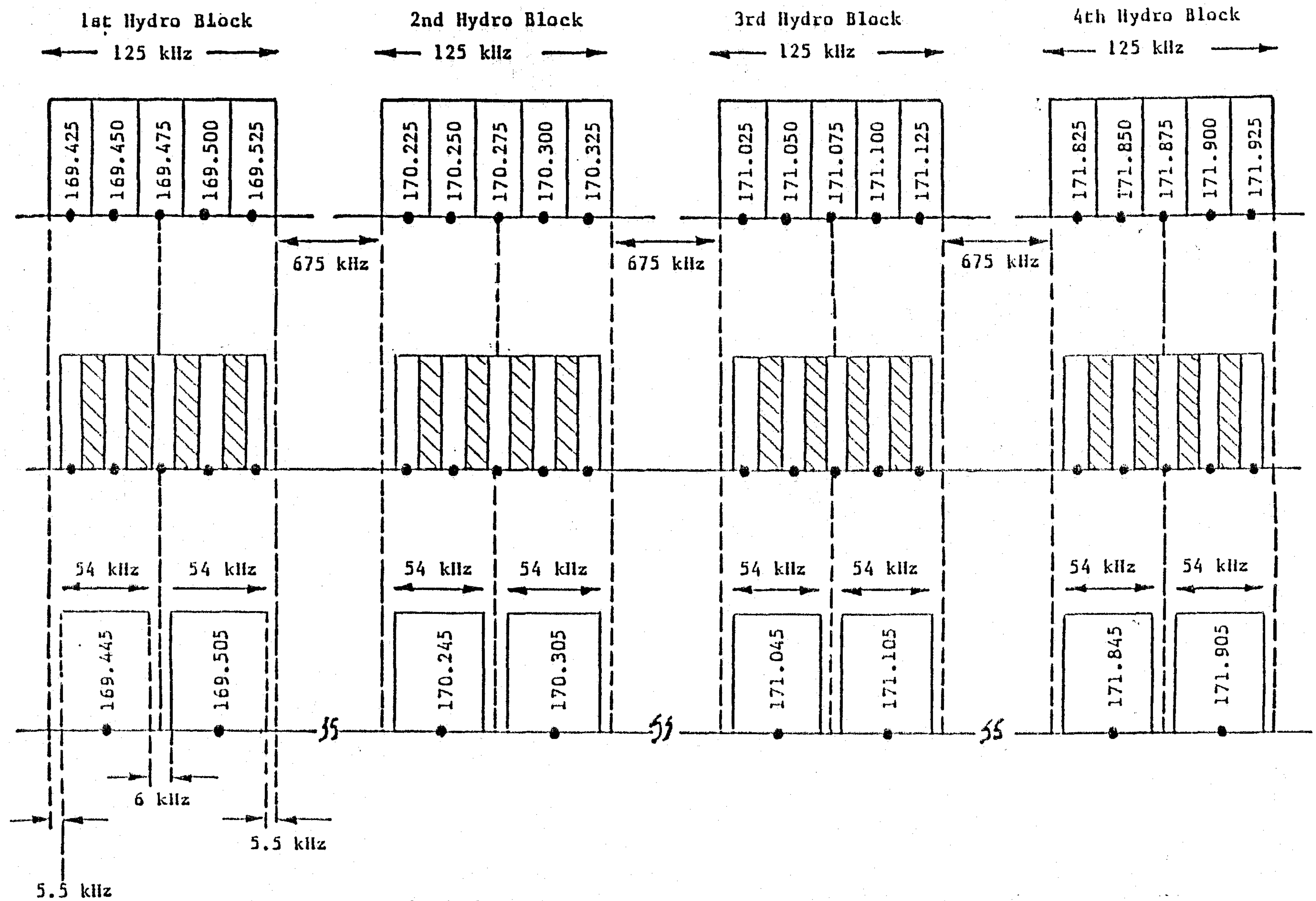


Figure 8-1. VHF Hydrologic Narrowband Channeling Plan Option: Care of hydrologic plus interstitial frequencies preserved.

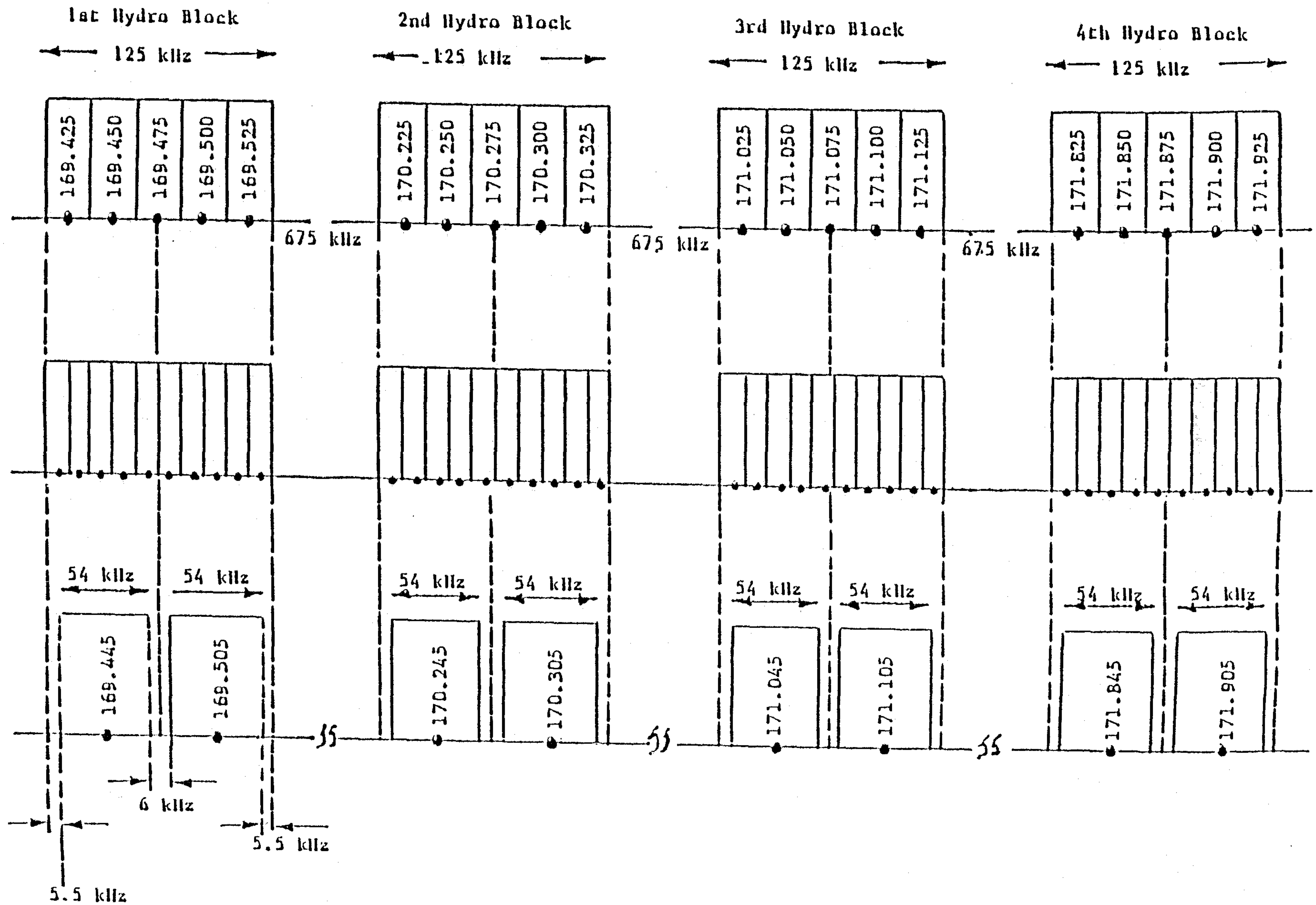


Figure 8-2. VHF Hydrologic Narrowband Channeling Plan Option: Care of hydrologic channels split, and hydrologic plus interstitial frequencies shifted.

APPENDIX A

HYDROLOGIC/NONHYDROLOGIC ASSIGNMENTS IN HYDROLOGIC CHANNELS

An automated retrieval of the GMF records based on the assigned frequency was performed for the 20 VHF and 8 UHF hydrologic channels, and for the 1 VHF and 1 UHF quasi-hydrologic channel. The majority of the VHF stations and all UHF stations correspond to the Fixed Service, and include hydrologic stations (FXH) or hydrologic repeater stations (FXHR), besides fixed (FX) or fixed repeater (FXR), fixed telecommand (FXD), or fixed telemetering (FXE).

The remaining VHF stations correspond to the Mobile or Land Mobile Service, or represent a few Experimental stations not associated with a specific service. The Mobile Service includes land (FL) or land repeater (FLR) stations, mobile (MO) or mobile portable (MOP) stations, and mobile hydrologic (MOH) stations. The Land Mobile Service includes base (FB), land mobile (ML), and land mobile portable (MLP) stations. There are only three stations in the Mobile Service associated with hydrologic operations, and the rest represent nonhydrologic operations. All stations in the Land Mobile Service represent nonhydrologic operations.

The actual number of assignments is fewer than the total number of stations, because many assignments contain multiple station entries. A dual station entry per assignment occurs frequently: the same assignment contains two station entries from distinct classes, usually one hydro (FXH or FXHR) and one fixed (FX or FXR). The hydro entry usually has an F2D emission designator corresponding to an FM signal with a digital-data subcarrier modulation, while the fixed entry usually has an F3E emission designator corresponding to an FM signal with single-channel analog voice modulation.

There are also various hydrologic channel assignments that have only one station entry, with one or more emission designators. When a dual entry occurs, the pairings can happen in many ways (e.g., FX with FX, FXH with FX, FXH with FXH, FXHR with FX, FXHR with FXR, FXHR with FXHR) and their corresponding emission pairs can also vary. There are also some assignments with multiple (more than two) stations (e.g., four distinct station classes per assignment with two emissions per class). These cases always correspond to the Mobile or Land Mobile Service, and involve nonhydrologic operations in the hydrologic channels.

The hydrologic channel assignments were analyzed in detail to develop a proper perspective of the diversification encountered. TABLES A-1 (VHF) and A-2 (UHF) provide a picture of the station class distribution by identifying the number and type of the single, dual, or multiple entry occurrences by agency and channel (each count in these tables represents one GMF assignment). For example, Agriculture has 5 assignments in the first VHF channel and all are dual entries of two types (4 FXH/FX, 1 FXHR/FXR), whereas Interior has 11 assignments

TABLE A-1
(page 1 of 4)

HYDROLOGIC/NONHYDROLOGIC ASSIGNMENTS IN VHF HYDROLOGIC CHANNELS

	FREQUENCIES (MHz)										
AGENCIES	169.425	169.450	169.475	169.500	169.525	170.225	170.250	170.275	170.300	170.325	171.025
AGRICULTURE 82 Total (82 Fixed)	4 FXH/ FX 1 FXHR/ FXR	6 FXH/ FX 2 FXHR/ FXR	1 FX/ FXH 4 FXHR/ FXR	2 FXHR/ FXR	4 FX/ FXH 1 FXHR/ FXR			15 FX/ FXH	4 FX/ FXH 2 FXHR/ FXR		6 FXH
ARMY 457 Total (454 Fixed; 3 Land Mobile)	2 FXH 21 FXH/ FX 1 FXHR/ FX 5 FXHR/ FXR 1 FXHR/ FXHR	22 FXH/ FX 9 FXH/ FXH 2 FXHR/ FX 6 FXHR/ FXR	8 FXH/ FX	10 FXH 7 FXH/ FX	8 FXH 1 FXHR 8 FXH/ FX 1 FXHR/ FX 15 FXHR/ FXR	6 FXH 7 FXH/ FX 1 FXHR/ FXR		2 FXH 11 FXH/ FX 11 FXHR/ FXR	6 FXH/ FX 2 FXH/ FXH 2 FXHR/ FXR	1 FXH 8 FXH/ FXH 1 ML	25 FXH 3 FXHR 8 FXH/ FX 2 FXHR/ FX 1 FXHR/ FXR
COMMERCE 727 Total (723 Fixed; 4 Experi-mental)	41 FXH 5 FXHR 3 FXH/ FXH 1 XT/XT	1 FXH 2 FXHR 1 XT/XT	28 FXH 2 FXHR	115 FXH 6 FXHR 5 FXH/ FXH	20 FXH 1 FXHR	22 FXH 2 FXHR	4 FXH 3 FXHR	40 FXH 1 FXHR	60 FXH 3 FXHR	1 FXH	31 FXH 2 FXHR
ENERGY 37 Total (35 Fixed) (2 Land Mobile)				21 FXH/ FX 3 FXHR/ FXR							
INTERIOR 100 Total (100 Fixed)	4 FXH 1 FXHR 6 FXH/ FX	7 FXH/ FX		2 FXH		13 FXH/ FX 2 FXHR/ FXR			4 FXH/ FX		3 FX 16 FXH/ FX 1 FXHR/ FXR
IBWC 7 Total (7 Fixed)	1 FXD/ FX 6 FXH/ FX										
NAVY 3 Total (3 Mobile)											

Note: Horizontal continuation of page 1 of table is on page A-3.
Vertical continuation of page 1 of table is on page A-4.

Horizontal continuation of page 3 of table is on page A-5.
Vertical continuation of page 2 of table is on page A-5.

TABLE A-1
(page 2 of 4)

AGENCIES	FREQUENCIES (MHz)									QUASI HYDRO
	171.050	171.075	171.100	171.125	171.825	171.850	171.875	171.900	171.925	171.175
AGRICULTURE	3 FXH/FX 2 FXHR/FXR	15 FXH/FX 5 FXHR/FXR	2 FXH/FX 1 FXHR/FX							2 FXH/FX
ARMY	1 FXH/FX		6 FXH 60 FXH/FX 15 FXHR/FXR	2 FXH/FX	5 FXH	12 FXH	1 FXH 70 FXH/FX 3 FXHR/FXR	40 FXH/FX 1 FXH/FXH 1 FXHR/FX 3 FXHR/FXR 1 FXHR/FXHR	1 FXHR/FXR 1 MLP	3 FX 1 FXR 1 FX/FX 3 FXH/FX 1 FXHR/FXR 1 ML
COMMERCE	42 FXH 7 FXHR	17 FXH 2 FXHR	91 FXH 7 FXHR	22 FXH 3 FXHR	27 FXH 10 FXHR 1 FXH/FXH	30 FXH 7 FXHR	7 FXR 1 FXHR	19 FXH 2 FXHR 1 XT/XT	29 FXH 2 FXHR 1 XT/XT	
ENERGY					11 FXH/FX					2 FB/ML/MLP
INTERIOR	1 FXH 1 FXH/FX 2 FXHR/FXR	15 FXH/FX 1 FXHR/FXR	4 FXH/FX		2 FXR				3 FXHR	2 FXE 7 FXH/FX 3 FXHR/FXR
IBWC										MO/MO
NAVY			3 MOH							

TABLE A-1
(page 3 of 4)

AGENCIES	FREQUENCIES (MHz) 169.425	169.450	169.475	169.500	169.525	170.225	170.250	170.275	170.300	170.325	171.025
NON-GOVT. 1350 Total (1348 Fixed) (2 Experimental)	98 FXH 1 FX/FX 1 FXH/FX		98 FXH 1 FX/FX 33 FXH/FX 7 FXH/FXH	135 FXH 23 FXH/FX 5 FXH/FXH	10 FX 99 FXH 1 XR	37 FX 107 FXH	17 FX 4 FXH 3 FXH/FX	1 FX 43 FXH 1 FXH/FX	136 FXH 12 FXH/FX	146 FXH 2 FX/FX	1 FXH 1 FXHR 1 XR
NRC 63 Total (63 Land Mobile)			21 FB				21 FB				
POSTAL SERVICE 1 Total (1 Land Mobile)											
SENATE 1 Total (1 Land Mobile)											
TENNESSEE VALLEY AUTHORITY 93 Total (93 Fixed)	8 FXH/FX 2 FXHR/FXR	7 FXH/FX 3 FXHR/FXR	9 FXH/FX 2 FXHR/FXR	11 FXH/FX 1 FXHR/FXR	2 FXH/FX 1 FXHR/FXR	4 FXH/FX 2 FXHR/FXR					
OTHERS 196 Total (191 Mobile) (5 Land Mobile)		1 FL/FL/FLR/FLR/MO/MO 81 FL/FL/FLR/FLR/MO/MO/MOP/MOP 8 MO/MO/MOP/MOP		2 FB/FB/ML/ML				2 FB/FB/ML/ML			
TOTALS											
2842 Fixed (2742 Hydros) 194 Mobile (3 Hydros) 75 Land Mobile (0 Hydros) 6 Experimental	212 Fixed (211 Hyd) 1 Experimental	67 Fixed (67 Hyd) 90 Mobile (0 Hyd) 1 Experimental	193 Fixed (192 Hyd) 21 Land Mobile (0 Hyd)	346 Fixed (346 Hyd) 2 Land Mobile (0 Hyd)	171 Fixed (161 Hyd) 1 Experimental	203 Fixed (166 Hyd)	31 Fixed (14 Hyd) 21 Land Mobile (0 Hyd)	125 Fixed (124 Hyd) 2 Land Mobile (0 Hyd)	231 Fixed (231 Hyd)	158 Fixed (156 Hyd) 1 Land Mobile (0 Hyd)	100 Fixed (97 Hyd) 1 Experimental
3117	213	158	214	348	172	203	52	127	231	159	101

TABLE A-1
(page 4 of 4)

AGENCIES	FREQUENCIES (MHz) 171.050	171.075	171.100	171.125	171.825	171.850	171.875	171.900	171.925	QUASI HYDRO 171.175
NON-GOVT.	24 FXH	9 FXH	1 FX 36 FXH	13 FX 120 FXH	6 FXH 1 FXHR 1 FXH/FXH	21 FXH 1 FXHR	35 FXH 3 FXH/FX 1 FXH/FXH	4 FX 9 FXH	17 FXH 1 FXR 2 FXHR 1 FX/FX 20 FXH/FX	
NRC	21 FB									
POSTAL SERVICE										1 FB/ML
SENATE										1 FB/FB
TENNESSEE VALLEY AUTHORITY					4 FXH/FX 2 FXHR/FXR	6 FXH/FX 2 FXHR/FXR	9 FXH/FX 3 FXHR/FXR	8 FXH/FX 3 FXHR/FXR	2 FXH/FX 2 FXHR/FXR	
OTHERS		1 MO/MO 90 MO/MO/MOP/MOP								1 FLR/FLR 5 MO/MO 1 FB/FB/ML/ML 4 FL/FL/MO/MO
	83 Fixed (83 Hyd) 21 Land Mobile (0 Hyd)	64 Fixed (64 Hyd) 91 Mobile (0 Hyd)	223 Fixed (222 Hyd) 3 Mobile (3 Hyd)	160 Fixed (147 Hyd)	70 Fixed (68 Hyd)	79 Fixed (79 Hyd)	133 Fixed (133 Hyd)	91 Fixed (87 Hyd) 1 Experimental	79 Fixed (78 Hyd) 1 Land Mobile (0 Hyd) 1 Experimental	23 Fixed (16 Hyd) 10Mobile (0 Hyd) 6 Land Mobile (0 Hyd)
	104	155	226	160	70	79	133	92	81	39

TABLE A-2

UHF HYDROLOGIC CHANNELS

AGENCIES	FREQUENCIES								QUASI HYDRO
	M406.125	M406.175	M406.675	M409.725	M412.625	M412.675	M412.725	M412.775	M406.150
AGRICULTURE 5 Total (5 Fixed)		1 FXHR/FX 1 FXHR/FXR			2 FXH/FX				1 FXH
ARMY 16 Total (16 Fixed)	2 FXH	1 FXH 1 FXH/FX 1 FXHR/FXR			1 FXHR/FXR	1 FXH		8 FXH 1 FXHR/FXR	
COMMERCE 33 Total (33 Fixed)	2 FXH	22 FXH			1 FXH 1 FXHR			7 FXH	
ENERGY 4 Total (4 Fixed)	1 FXH/FX						1 FXHR/FXR		2 FXD
FEMA 1 Total (1 Fixed)									1 FX
INTERIOR 59 Total (59 Fixed)	2 FXD/FX 11 FXH/FX 1 FXH/FXD	1 FXD 30 FXH/FX	1 FXD 1 FXH 1 FXHR/FXR		2 FXHR/FXR			3 FXH/FX 1 FXHR/FXR	3 FXE 1 FXH/FX 1 FXHR/FXR
NAVY 1 Total (1 Fixed)									1 FXH
NON-GOVERNMENT 113 Total (113 Fixed)	1 FX 30 FXH 21 FXH/FX	1 FX 14 FXH	1 FXHR		1 FX 22 FXH 1 FXH/FX 1 FXHR/FXR	7 FXH 1 FXH/FX	9 FXH 1 FXH/FX	2 FX	
TENNESSEE VALLEY AUTHORITY 145 Total (145 Fixed)	5 FXH/FX	6 FXH/FX		2 FXH/FX	39 FXH/FX	34 FXH/FX	25 FXH/FX	34 FXH/FX	
OTHER 1 Total (1 Land Mobile)									1 MLP/MLP
TOTALS									
377 Fixed (362 Hydros) 1 Land Mobile (0 Hydros)	76 Fixed (73 Hydros)	79 Fixed (77 Hydros)	4 Fixed (3 Hydros)	2 Fixed (2 Hydros)	71 Fixed (70 Hydros)	43 Fixed (43 Hydros)	36 Fixed (36 Hydros)	56 Fixed (54 Hydros)	10 Fixed (4 Hydros) 1 Land Mobile (0 Hydros)
378	76	79	4	2	71	43	36	56	11

in the first VHF channel and they are 5 single entries of two types (4 FXH, 1 FXHR) and 6 dual entries of one type (6 FXH/FX).

The Fixed Service assignments consist of single or dual station entries, whereas the Mobile or Land Mobile Service assignments consist of single, dual, or multiple station entries. The hydrologic operations consist of single or dual fixed stations, plus three mobile stations, and represent 88.1% (VHF) and 95.8% (UHF) of the assignments.

The last row in TABLES A-1 (VHF) and A-2 (UHF) provides the service breakdown by channel and total, including how many of the service assignments are involved in hydrologic operations. The Fixed Service represents 91.2% (VHF) and 99.7% (UHF) of the assignments, with 88.0% (VHF) and 95.8% (UHF) involved in hydrologic operations. The Mobile and Land Mobile Service represent 8.6% (VHF) and 0.3% (UHF) of the assignments, with only 0.1% (VHF) and none (UHF) involved in hydrologic operations. The Experimental stations represent only 0.2% (VHF) and none (UHF) of the assignments.

The hydrologic channels were also analyzed individually to identify the emission characteristics (modulation, bandwidth, power) specified for each station class occurrence. The modulation designators are F2D or F3E for most emissions, corresponding to frequency modulation by a digital-data subcarrier (F2D) or by analog single-channel voice (F3E). The other modulation designators encountered are A1B (1 nongovernment VHF assignment), F1D (5 nongovernment VHF and 2 government UHF assignments), L2D (44 nongovernment VHF assignments), and F1E/F3E (196 government VHF assignments).

The emission bandwidth distribution by agency is shown in TABLES A-3 (VHF) and A-4 (UHF). A 16 kHz bandwidth is the predominant mode occurring in 84.1% (VHF) and 66.5% (UHF) of the emissions. A 20 kHz bandwidth is the only higher value encountered, and is only associated with nongovernment assignments representing 14.2% (VHF) and 10.0% (UHF) of the emissions. Other smaller bandwidth values are the exception in the VHF assignments (1.7%), but not in the UHF assignments (23.5%).

The specified power distribution for the hydrologic channel emissions is shown in TABLES A-5 (VHF) and A-6 (UHF). Some relatively high power emissions can occur, even after all nonhydrologic operations are excluded. For example, of the VHF hydrologic channel entries with 90 W or more power, there are still 147 emissions representing hydrologic operations, after 799 emissions representing nonhydrologic operations are excluded.

TABLE A-3

BANDWIDTH DISTRIBUTION FOR ALL EMISSIONS IN VHF HYDROLOGIC CHANNELS

AGENCIES	0.1 kHz	2.5 kHz	3.0 kHz	4.5 kHz	5.0 kHz	5.6 kHz	10 kHz	15 kHz	16 kHz	20 kHz
AGRICULTURE (158)									158	
ARMY (825)					1				824	
COMMERCE (741)			1				1		739	
ENERGY (76)									76	
INTERIOR (182)							2		180	
IBWC (14)									14	
NAVY (3)									3	
NON-GOVERNMENT (1465)	1	9		45		7		6	710	687
NRC (63)									63	
POSTAL SERVICE (2)									2	
SENATE (2)									2	
TVA (186)							7		179	
OTHERS (1096)									1096	
TOTALS (4813)	1	9	1	45	1	7	10	6	4046	687

Note: There are 3508 emissions associated with hydrologic operations, and 1305 emissions associated with nonhydrologic operations. The nonhydrologic emissions have 16 kHz (1303 entries) or 20 kHz (2 entries) as assigned bandwidth.

TABLE A-4

BANDWIDTH DISTRIBUTION FOR ALL EMISSIONS IN UHF HYDROLOGIC CHANNELS

AGENCIES	5.0 kHz	5.6 kHz	10 kHz	12 kHz	15 kHz	16 kHz	20 kHz
AGRICULTURE (9)						9	
ARMY (20)						20	
COMMERCE (33)					2	31	
ENERGY (6)						6	
FEMA (1)						1	
INTERIOR (112)	2		1			109	
NAVY (1)				1			
NON-GOVERNMENT (138)		10			31	36	61
TVA (290)			97			193	
OTHER (2)						2	
TOTALS (612)	2	10	98	1	33	407	61

Note: There are 597 emissions associated with hydrologic operations, and 15 emissions associated with nonhydrologic operations. The nonhydrologic emissions always have 16 kHz as assigned bandwidth.

TABLE A-5

POWER DISTRIBUTION FOR ALL EMISSIONS IN VHF HYDROLOGIC CHANNELS

	TX POWER (WATTS)																		
AGENCIES	0.05	0.1-0.5	1-4	5-8	10-12	15-18	20-25	30-35	40	50	60-65	70-72	80	90	100	110	120	150	250
AGRICULTURE (158)				39	79		30					2	8						
ARMY (825)		2	9	267	10	171	88	152		62	29		4	7	11	8	4	1	
COMMERCE (741)				581	21	12	108		1	1	12				3	2			
ENERGY (76)				18		54									4				
INTERIOR (182)		2	8	24	68		70			2	4				2	2			
IBWC (14)									12						2				
NAVY (3)			3																
NON-GOVERNMENT (1465)		2	7	206	67	5	830	121	10	11	2	22	4	1	18	159			
NRC (63)	63																		
POSTAL SERVICE (2)				1			1												
SENATE (2)																			2
TVA (186)							12	170				4							
OTHERS (1096)					358				8		10				4	716			
TOTALS (4813)	63	6	27	1136	603	242	1139	443	31	76	57	28	16	8	44	887	4	1	

TABLE A-6

POWER DISTRIBUTION FOR ALL EMISSIONS IN UHF HYDROLOGIC CHANNELS

AGENCIES	0.1-0.5 W	1-4 W	8-10 W	12-15 W	20-25 W	30 W	40-45 W	70 W	80 W	100 W	110 W
AGRICULTURE (9)			1		4			2	2		
ARMY (20)		12		8							
COMMERCE (33)		33									
ENERGY (6)	2			4							
FEMA (1)										1	
INTERIOR (112)	3	4	6	12	24	63					
NAVY (1)		1									
NON-GOVERNMENT (138)		50	16	24	30	4	6			2	6
TENNESSEE VALLEY AUTHORITY (290)		2			248	40					
OTHER (2)	2										
TOTALS (612)	7	102	23	48	306	107	6	2	2	3	6

APPENDIX B

HYDROLOGIC ASSIGNMENTS IN NONHYDROLOGIC CHANNELS

Further investigation of the GMF revealed that hydrologic operations are being conducted in the nonhydrologic channels by both government and nongovernment agencies. Most of the agencies with hydrologic operations in hydrologic channels also have hydrologic operations in the nonhydrologic channels. There are also agencies using nonhydrologic channels for hydrological operations without any assignments in the hydrologic channels.

A total of 28 VHF and 11 UHF nonhydrologic channels were identified as being used by government and nongovernment agencies for hydrologic operations. The number and frequencies of the channels used by each agency are presented in TABLES B-1 (VHF) and B-2 (UHF). Some of these channels are used by more than one agency for hydrologic operations.

A total of 384 (VHF) and 15 (UHF) assignments representing hydrologic operations were identified for these nonhydrologic channels. The distribution by agency of the assignments, station classes, emission types, and power specifications is shown in TABLES B-3 (VHF) and B-4 (UHF). The assignments exhibit single, dual, or multiple station occurrences, as happened with the hydrologic channel assignments.

The distribution of the station classes and emission characteristics also follow the same pattern exhibited by the hydrologic channel assignments. The majority of the stations correspond to the Fixed Service, with 96% (VHF) and 93% (UHF) of the assignments, and the rest correspond to the Mobile and Land Mobile Services. The predominant emission types are again 16KF2D (FM digital-data subcarrier) and 16KF3E (FM analog single-channel voice), which represent 91% (VHF) and 55% (UHF) of all emissions. The bandwidth specification again never exceeds 20 kHz, and the diversity in the power specification is again evident.

TABLE B-1

NONHYDROLOGIC CHANNELS USED FOR HYDROLOGIC OPERATIONS IN THE VHF BAND

AGENCIES	CHANNELS USED	FREQUENCIES (MHz)
AGRICULTURE	5	164.1500, 166.6750 169.2750, 169.5750 170.3750
AIR FORCE	1	173.4375
ARMY	6	163.4125, 165.0375 165.1625, 169.5750 170.3750, 171.9750
COMMERCE	5	162.1500, 163.3000 166.0750, 169.0250 170.1000
ENERGY	1	163.7937
FAA	1	165.7375
INTERIOR	10	163.0250, 164.4250 164.4750, 166.2000 166.8000, 166.9250 169.5750, 170.0000 170.3750, 171.9750
INTERNATIONAL BORDER AND WATER COMMISSION	2	172.4750, 173.1750
NON-GOVERNMENT	2	169.5750, 170.3750
TENNESSEE VALLEY AUTHORITY	3	162.0250, 172.0250

TABLE B-2

NONHYDROLOGIC CHANNELS USED FOR HYDROLOGIC OPERATIONS IN THE UHF BAND

AGENCIES	CHANNELS USED	FREQUENCIES (MHz)
ARMY	2	406.2500, 407.5500
ENERGY	2	408.4906, 409.8656
INTERIOR	3	406.2500, 411.6250 411.6500
INTERNATIONAL BORDER AND WATER COMMISSION	1	412.1250
NON-GOVERNMENT	5	406.2500, 406.3750 409.9250, 409.9500 410.0750

TABLE B-3

HYDROLOGIC ASSIGNMENTS IN NONHYDROLOGIC VHF CHANNELS

AGENCIES	NO. OF HYDRO ASSIGNMENTS IN NON-HYDRO FREQUENCIES	STATION CLASS OCCURRENCES (TOTAL)	BANDWIDTH AND MODULATION TYPE OCCURRENCES (TOTAL)	POWER OCCURRENCES (TOTAL)
AGRICULTURE	41	FLH/FL (2) FLHR/FLR (2) FX (1) FXH (2) FXH/FX (62) FXHR/FXR (2) MOH/MO (6) MOHR/MOR (2)	16KF2D (76) 16KF3D (2) 16KF3E (77)	2W (4) 5W (41) 8W (1) 10W (8) 20W (2) 25W (93) 60W (8)
AIR FORCE	2	FXH (2)	6KF2D (2)	10W (2)
ARMY	43	FXH (11) FXH/FX (28) FXHR/FXR (4)	15KF2D (28) 16KF2D (16) 16KF2E (1) 16KF3E (29) 16KF3F (1)	2W (2) 3W (1) 4W (26) 5W (8) 8W (10) 10W (2) 18W (6) 15W (4) 50W (2) 20W (4) 70W (4) 60W (6)
COMMERCE	157	FXH (141) FXHR (5) FXH/FX (3) FXH/FXH (7) FXHR/FXHR (1)	10KF2D (12) 16KF3D (139) 16KF3E (16)	2W (4) 8W (132) 10W (14) 15W (3) 20W (4) 25W (9) 40W (2)
ENERGY	1	FXH (1)	9KF3DFN (1)	2W (1)
FAA	2	FXH (2)	16KF2D (2)	5W (2)
INTERIOR	117	F3R (1) FXER (1) FXH (6) FXH/FX (107) FXHR/FXR (3) ML (1)	16KF2D (118) 16KF3E (112)	4W (96) 8W (42) 10W (2) 15W (6) 25W (40) 30W (2) 40W (28) 50W (2) 60W (3) 110W (9)
INTERNATIONAL BORDER AND WATER COMMISSION	6	FXH/FX (3) FXHR (1) FXHR/FXR (2) MO (2)	16KF2D (6) 16KF3E (8)	15W (6) 60W (4) 100W (4)
NON-GOVERNMENT	14	FXH (8) FXH/FX (6)	16KF2D (1) 20KF2D (11) 20KF3E (8)	30W (6) 72W (12) 120W (2)
TENNESSEE VALLEY AUTHORITY	3	FXHR (1) FXH/FX (2)	16KF2D (3) 16KF3E (3)	2W (1) 60W (4)

TABLE B-4

HYDROLOGIC ASSIGNMENTS IN NONHYDROLOGIC UHF CHANNELS

AGENCIES	NO. OF HYDRO ASSIGNMENTS IN NON-HYDRO FREQUENCIES	STATION CLASS OCCURRENCES (TOTAL)	BANDWIDTH AND MODULATION TYPE OCCURRENCES (TOTAL)	POWER OCCURRENCES (TOTAL)
ARMY	2	FXH (1) MOH (1)	3K61D (1) 15KF2D (1)	2W (2)
ENERGY	2	FXH (2)	5KF2D (2)	0.4W (2)
INTERIOR	5	FXH (1) FXH/FX (4) FXHR/FXR (1)	16KF2D (5) 16KF3E (4)	5W (4) 15W (4) 100W (1)
INTERNATIONAL BORDER AND WATER COMMISSION	1	FXHR/FXR (1)	16KF2D (1) 16KF3E (1)	20W (2)
NON-GOVERNMENT	5	FXH (5)	12KF2D (5)	1W (5)

APPENDIX C

WIRELESS MICROPHONE ASSIGNMENTS IN WIRELESS MICROPHONE CHANNELS

Wireless microphone operations have been authorized on an unprotected basis to certain frequencies located within the VHF hydrologic channel blocks, provided they do not interfere with other authorized government and nongovernment operations in the band. The wireless microphone operations are restricted to eight specific frequencies, with 54 kHz maximum emission bandwidth and 50 milliwatts maximum output power, and their emissions are limited to within ± 32.5 kHz of their assigned frequency.

The GMF database (April 1989) was accessed to retrieve records on the wireless microphone operations in the 162-174 MHz band. A total of 3,721 government and nongovernment assignments were found in the eight frequencies, and 3,653 (98%) of them are allocated to the nongovernment sector. The other 68 (2%) government assignments are distributed among 13 government agencies.

The wireless microphone records were analyzed to identify the various station classes, modulation types, emission bandwidths, and power specifications, and the distribution by agency and frequency are shown in TABLES C-1 to C-3. All stations correspond to the Land Mobile Service, with 99% of them representing land mobile (LM) stations, and the rest being land mobile portable (MLP) or base (FB) stations.

The modulation type and emission bandwidth employed varies with different agencies, but remains very consistent throughout the eight channels for a given agency. The predominant emission designators are 8KA3E (8 kHz DSB/AM analog voice), 20KF3E (20 kHz FM analog voice), and 54KF3E (54 kHz FM analog voice). The power specification is 50 milliwatts in 94% of the wireless microphone operations.

TABLE C-1

STATION CLASS DISTRIBUTION FOR ALL WIRELESS MICROPHONE CHANNEL ASSIGNMENTS

AGENCIES (Total Assignments)	FREQUENCIES (MHz)							
	169.4450	169.5050	170.2450	170.3050	171.0450	171.1050	171.8450	171.9050
AIR FORCE (14)	ML (3)	ML (2)	ML (1)	ML (1)	ML (1)	ML (2)	ML (1)	ML (3)
ARMY (14)	MLP (1)	MLP (3)	MLP (1)	MLP (2)	MLP (2)	MLP (3)	MLP (1)	MLP (1)
ADMINISTRATIVE OFFICE OF THE U.S. COURTS (2)		ML (1)	ML (1)					
COMMERCE (2)	ML (1)					ML (1)		
ENERGY (6)		ML (2)			FB (1) ML (1) MLP (1)			ML (2)
FEDERAL EMERGENCY MANAGEMENT AGENCY (6)	ML (1)	ML (1)			ML (1)	ML (1)	ML (1)	ML (1)
HEALTH AND HUMAN SERVICES (2)	MLP (1)							MLP (1)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (3)		MLP (1)	MLP (1)					MLP (1)
NAVY (5)	ML (1)		ML (1)			ML (2)	ML (1)	
NON-GOVERNMENT (3,653)	ML (205) XD (5)	ML (106)	ML (1319)	ML (297)	ML (108)	ML (1304)	ML (114)	ML (198) XD (5)
STATE (4)	ML (1)			ML (1)	ML (1)		ML (1)	
U.S. POSTAL SERVICE (2)		ML (1)						ML (1)
VETERANS ADMINISTRATION (7)	ML (1)		ML (2)		ML (1)			ML (3)
OTHER (1)				MLP (1)				

TABLE C-2

POWER DISTRIBUTION FOR ALL WIRELESS MICROPHONE CHANNEL ASSIGNMENTS

AGENCIES (Total Assignments)	FREQUENCIES (MHz)							
	169.4450	169.5050	170.2450	170.3050	171.0450	171.1050	171.8450	171.9050
AIR FORCE (14)	50mW (3)	50mW (2)	50mW (1)	50mW (1)	50mW (1)	50mW (2)	50mW (1)	50mW (3)
ARMY (14)	50mW (1)	50mW (3)	50mW (1)	50mW (2)	50mW (2)	50mW (3)	50mW (1)	50mW (1)
ADMINISTRATIVE OFFICE OF THE U.S. COURTS (2)		5mW (1)	5mW (1)					
COMMERCE (2)	15mW (1)					15mW (1)		
ENERGY (6)		50mW (2)			50mW (3)			50mW (2)
FEDERAL EMERGENCY MANAGEMENT AGENCY (6)	50mW (1)	50mW (1)			50mW (1)	50mW (1)	50mW (1)	50mW (1)
HEALTH AND HUMAN SERVICES (2)	50mW (1)							50mW (1)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (3)		50mW (1)	50mW (1)					50mW (1)
NAVY (5)	50mW (1)		50mW (1)			50mW (2)	50mW (1)	
NON-GOVERNMENT (3,653)	3mW (1) 5mW (1) 25mW (3) 50mW (205)	20mW (1) 25mW (3) 50mW (102)	20mW (1) 25mW (2) 50mW (1316)	25mW (184) 30mW (1) 50mW (112)	20mW (1) 25mW (3) 50mW (104)	25mW (4) 50mW (1300)	20mW (1) 25mW (2) 50mW (111)	3mW (1) 15mW (1) 20mW (1) 25mW (2) 50mW (198)
STATE (4)	50mW (1)			50mW (1)	50mW (1)		50mW (1)	
U.S. POSTAL SERVICE (2)		50mW (1)						50mW (1)
VETERANS ADMINISTRATION (7)	50mW (1)		50mW (2)		50mW (1)			50mW (3)
OTHER (1)				50mW (1)				

TABLE C-3

EMISSION DESIGNATOR FOR ALL WIRELESS MICROPHONE CHANNEL ASSIGNMENTS

AGENCIES (Total Assignments)	FREQUENCIES (MHz)							
	169.4450	169.5050	170.2450	170.3050	171.0450	171.1050	171.8450	171.9050
AIR FORCE (14)	54KF3E(3)	54KF3E(2)	54KF3E(1)	54KF3E(1)	54KF3E(1)	54KF3E(2)	54KF3E(1)	54KF3E(3)
ARMY (14)	54KF3E(1)	16KF3E(2) 54KF3E(1)	54KF3E(1)	54KF3E(2)	54KF3E(2)	16KF3E(2) 54KF3E(1)	54KF3E(1)	54KF3E(1)
ADMINISTRATIVE OFFICE OF THE U.S. COURTS (2)		54KF3E(1)	54KF3E(1)					
COMMERCE (2)	12KF3E(1)					12KF3E(1)		
ENERGY (6)		32K05F3E(1) 54KF3E(1)			32KF3E(2) 32K05F3E(1)			32KF3E(1) 32KF3E(1)
FEDERAL EMERGENCY MANAGEMENT AGENCY (6)	8KF3E(1)	8KF3E(1)			8KF3E(1)	8KF3E(1)	8KF3E(1)	8KF3E(1)
HEALTH AND HUMAN SERVICES (2)	54KF3E(1)							54KF3E(1)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (3)		30KF3E(1)	30KF3E(1)					30KF3E(1)
NAVY (5)	30KF3E(1)		30KF3E(1)			18KF3E(1) 30KF3E(1)	18KF3E(1)	
NON-GOVERNMENT (3,653)	8KA3E(41) 15KF3E(4) 20KF3E(104) 44KF3E(5) 54KF3E(56)	8KA3E(41) 15KF3E(3) 20KF3E(8) 44KF3E(1) 54KF3E(53)	8KA3E(41) 15KF3E(1) 16KF3E(9) 20KF3E(1202) 44KF3E(6) 54KF3E(60)	8KA3E(41) 15KF3E(191) 16KF3E(2) 20KF3E(9) 44KF3E(1) 54KF3E(53)	8KA3E(41) 15KF3E(3) 20KF3E(8) 44KF3E(4) 54KF3E(52)	8KA3E(41) 15KF3E(3) 16KF3E(9) 20KF3E(1197) 44KF3E(1) 54KF3E(53)	8KA3E(41) 15KF3E(1) 20KF3E(8) 44KF3E(4) 54KF3E(60)	8KA3E(41) 12KF3E(1) 15KF3E(2) 20KF3E(100) 44KF3E(5) 54KF3E(54)
STATE (4)	36KF3E(1)			36KF3E(1)	36KF3E(1)		36KF3E(1)	
U.S. POSTAL SERVICE (2)		30KF3E(1)						30KF3E(1)
VETERANS ADMINISTRATION (7)	8KA3E(1)		8KA3E(1) 20KF3E(1)		8KA3E(1)			8KA3E(2) 20KF3E(1)
OTHER (1)				16KF3E(1)				

LIST OF REFERENCES

1. Bedrosian, E. and W. Sollfrey (1989), *A Comparison of SSB-SC and Conventional AM under a Peak Power Limitation*, IEEE Trans. on Communications, Vol. 37, No. 1, January.

2. Cohen, D., W. Grant and F. Steele (1989), Meteor Burst System Communications Compatibility, NTIA Report 89-241, March.

3. Crandall, G. A. (1982), *Spectrum Resource Assessment in the 406.1-420 MHz Band*, NTIA Report 82-91, January.

4. Flynn, F. P. and W. M. Moran (1984), *Spectrum Resource Assessment in the 162-174 MHz Band*, NTIA Report 84-143, February.

5. IRAC Documents on Hydrologic Channels, Hydrologic Operations, Wireless Microphone Channels, and Wireless Microphone Operations: Document Nos. 23082/1, 23119/1, 23135/2, 23162/1, 23229/1, 24210/1, 25048/1, 25121/1, 25123/1, 25159/1, 25161/2, 25796/1, 25817/1, 25819/1, 25841/1, 25843/1, 25874/1, 26223/1, 26315/1, 26321/1, 26241/1.

6. IRAC Document 26332 (AGENDA) (1989), Allocation of the Subbands 932-932.5 MHz and 941-941.5 MHz to Government and Nongovernment Fixed Service for Single-Channel, Point-to-Multipoint Operations, February 28.

7. NTIA, *Manual of Regulations and Procedures for Federal Radio Frequency Management*, U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, DC, January 1989 Revision.

8. Shelton, W., D. Cohen, G. Crandall, G. Hurt and W. Speights (1984), *Assessment of Narrowband Modulation Technologies for Government Land Mobile Operations*, NTIA Report 84-156, August.

9. Sklar, B. (1983), *A Structural Review of Digital Communications*, IEEE Communications Magazine, August.

10. Wacker, J. and S. Cohn (1986), *Land Mobile Narrowband Technologies, EMC Technology*, September-October.

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report presents a detailed assessment of the hydrologic and meteorological operations in the 162-174 MHz (VHF) and 406.1-420 MHz (UHF) bands. These operations are currently supported by hydrologic and quasi-hydrologic channel assignments in these bands. There is a current need to jointly support hydrologic and nonhydrologic operations representing important national programs, and to develop solutions that alleviate spectral congestion and promote efficient spectrum utilization. This report identifies current regulations and channel usage, and analyzes the hydrologic emission characteristics to assess their bandwidth requirements and conservation alternatives. The current hydrologic channeling plans are also analyzed, and narrowband channeling options are assessed, along with the potential hydrologic service reaccommodation in current or other bands. All potential relocation and channeling options are explained and compared to illustrate their impact, tradeoffs, and compromises. The results of this study can serve to improve the spectral efficiency of hydrologic operations while remaining cost effective, and to conserve spectrum that can be made available for additional uses.

16. Key Words *(Alphabetical order, separated by semicolons)*

162-174 MHz Band; 406.1-420 MHz Band; Hydrologic Operations; Narrowband Channeling Plans; Spectrum Conservation; Wireless Microphones

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