SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

DISCUSSION OF RESULTS

This study assessed three candidate frequency bands (216-225 MHz, 400.15-406 MHz, 420-450 MHz) for the potential accommodation of Wind Profilers. While the primary concern was national accommodation, international considerations were also included. The Wind Profiler is a radar assumed to require accommodation on a primary basis for both government and non-government users as a radiolocation station or as a meteorological radar station. However, it is noted that for some requirements, secondary status could be acceptable.

Two distinct types of Wind Profilers are expected to be deployed nationally, which are referred to hereinafter as Type A and Type B. In general, Type A profilers are similar to those proposed by NOAA in their national network which is expected to eventually consist of 200-300 profilers. Type A profilers will be able to detect wind speed and direction at altitudes up to 15-20 km, depending on meteorological conditions. Type B profilers have different performance requirements and are less complex than Type A. These profilers will detect wind speed and direction at lower altitudes (i.e., 5-7 km). The expected number and overall deployment philosophy of Type B profilers is unknown. In addition, due to the larger bandwidth specified for Type B Wind Profilers (i.e., 4 MHz compared to 2 MHz for Type A), they cannot be easily accommodated in any of the three candidate frequency bands. Although several users have expressed interest in Type B profilers, spectrum certification in accordance with the NTIA Manual, Chapter 10, has not been requested. The following paragraphs provide a discussion on the main issues involved in assessing each of the candidate frequency bands for possible Wind Profiler accommodation.

216-225 MHz Band

In terms of technical performance, the 216-225 MHz band offers some advantages over the use of higher frequencies. However, the significant increased cost for the antenna at these frequencies may somewhat offset the performance advantage. In terms of national and international allocation, there is no existing provision for Wind Profiler operations, as either a radiolocation or meteorological aids device. To accommodate Wind Profilers, nationally, a change to the National Table of Frequency Allocations would be necessary, either directly to the Table or by footnote. In either case, an NTIA/IRAC decision and Federal Communications Commission (FCC) rulemaking proceeding would be required. The FCC rulemaking would include involvement from many interested parties (e.g., land-mobile, maritime mobile, amateurs, and adjacent band broadcasters) as well as the impact of the current Notice of Proposed Rulemaking (NPRM) proceedings dealing with the Maritime Mobile service.[1] If accommodation in this band were pursued, a new footnote specifically tailored to allow Wind Profiler operations is more desirable than adding a new allocation in the National Table of Frequency Allocations. In addition, according to Chapter 3 of the NTIA Manual, Wind Profiler operations in this band near the U.S.-Canada border would require coordination. Since this potential allocation change would be a national issue only, the national allocation accommodation of the Wind Profiler is

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1 SEE GENERAL Doc. 9056, 5 FCC 1255 (March 5, 1990).

assessed as **CONDITIONAL**. However, accommodation would depend on the outcome of the rulemaking process.

Internationally, for Wind Profilers to be accommodated on a primary basis in this band, the meteorological aids service would have to be added to the international table or the radiolocation service upgraded in Region 2. In Regions 1 and 3, the meteorological aids or radiolocation service would have to be added in the allocation band 174-223 MHz. Any allocation changes would involve acceptance at a future World Administrative Radio Conference (WARC). Furthermore, due to allocation changes resulting from WARC-79[2], it would be difficult to accommodate Wind Profilers as a radiolocation or meteorological radar station. In addition, sharing of this band may be difficult since it is mostly allocated to broadcasting on a primary basis. As a result, this band is considered **UNSUITABLE** internationally.

Compatible operation of Wind Profilers in the 216-225 MHz band may be possible in some geographic areas of the US, subject to coordination and/or case-by-case EMC analysis. Based on sharing considerations, the frequency 219 MHz (2 MHz necessary bandwidth) is found to be the most suitable frequency in this range. This frequency minimizes potential interference to TV broadcast operations in the lower adjacent band and avoids sharing with the expected heavy concentration of land mobile and amateur use in the upper adjacent band. Type B profilers, due to bandwidth requirements, could not be accommodated in this band. A detailed study of the potential interference to TV-13 receivers would be required before any widespread wind profiler operations could be considered in the 216-225 MHz band. The expected expansion of the maritime mobile service in the 216-220 MHz portion also impacts sharing. The national EMC assessment of this band is considered **CONDITIONAL**.

In summary, based on the national and international allocation and national EMC assessments, the 216-225 MHz is considered **CONDITIONAL** nationally and **UNSUITABLE** internationally.

400.15-406 MHz Band

In terms of conformance to National and International Tables of Frequency Allocations, Wind Profilers operating as a meteorological aids device could be allocated on a primary basis worldwide for all users with only a minor change to the National Table of Frequency Allocations. This change would add Wind Profilers or delete the limitation to radiosondes, nationally. As a result, Wind Profilers accommodation, in terms of allocation is **CONDITIONAL,** nationally, and **SUITABLE** internationally.

Based on the EMC assessment, neither Type A nor Type B profilers can operate in the 400.15-406 MHz band without shutting down to prevent interference to the COSPAS/SARSAT satellites passing overhead. From a regulatory viewpoint, this shutdown is not considered to be an acceptable or effective means to ensure the necessary protection requirement for a safety-of-life service.

Several U.S. government agencies as well as various administrations (i.e., Canada and France) have requested that the 400.15-406 MHz band not be considered a candidate band for

2 Radiolocation service was reduced to secondary status. Footnote RR627 does not allow new radiolocation systems to be added in Region 2 after January 1, 1990.

Wind Profiler operations since crucial satellite operations in the band as well as the COSPAS/SARSAT operations in the adjacent 406-406.1 MHz band may be jeopardized.

Future enhancements to the current 404.37 MHz Wind Profiler design may improve compatibility between the Wind Profiler and COSPAS/SARSAT. However, due to the potential national and international regulatory burdens associated with, 1) developing and gaining worldwide acceptance and enforcement of spectrum and operational standards to ensure compatibility with COSPAS/SARSAT, 2) adopting interference reporting and mitigation procedures, and 3) resolving equipment malfunction and human error concerns, the EMC assessment of this band is considered **UNSUITABLE.**

In summary, based on the EMC assessment, the 400.15-406 MHz is considered **UNSUITABLE**, both nationally and internationally for Wind Profiler operations.

<u>420-450 MHz Band</u>

In terms of national allocations, the 420-450 MHz band is allocated on a primary basis to the radiolocation service. However, the band is not available to all users (Government non-military and non-Government) because footnote G2 limits Government use to the military and there is no provision for non-Government use. This band is the only 30 MHz of spectrum available for military radiolocation below 1 GHz nationally. To accommodate all Wind Profiler users, a change to the National Allocation Table would be necessary, either directly to the Table or by footnote. In either case, an NTIA/IRAC decision and FCC rulemaking proceeding would be required. Adding a new U.S. footnote allowing Government and non-Government Wind Profiler operations is more desirable than adding a new allocation in the National and International Table of Frequency Allocations. Internationally, Wind Profilers could be accommodated in the 430-440 MHz portion of the band since it is currently allocated on a primary basis to the radiolocation service. For Wind Profilers to be accommodated in the 420-430 MHz or 440-450 MHz portion of the band on a primary basis, an upgrade of the current radiolocation service to primary would be required. This change may involve acceptance at a future WARC. In the band 420-450 MHz, Wind Profiler operations must be coordinated with Canada. As a result, the allocation assessment of the 420-450 MHz band is **CONDITIONAL**, nationally and internationally.

Nationally, the 420-450 MHz band is used extensively by 1) the military for radiolocation systems that are at fixed locations and mobile (including airborne), 2) the military for drone operations at various test ranges, and 3) the amateurs for various functions on a secondary basis. Large, fixed-location radars are relatively few in number; presently there are approximately seven widely dispersed throughout the country. Although these fixed-location radar operations are not restricted in location and may be operated anywhere in the future, rapid expansion is not expected. Coordinated sharing between Wind Profilers and these fixed-location radars appears practical. Sharing between Wind Profilers and airborne platforms (i.e., airborne radars and drones) poses the greatest spectrum management difficulty because of the large frequency and distance separations required. Most of the military radiolocation and drone systems have the capability to operate over all or part of the 420-450 MHz band. Discussion of the three subbands within this range is given below.

The 420-430 MHz portion of the band currently contains the highest number of Government Master File (GMF) assignments of the three sub-bands. The military has many assignments for radiolocation and drone control operations, including flight termination at

425 MHz. The band is also allocated on a secondary basis to the amateur service and used predominately for Amateur TV (ATV) operations on two channels (420-426 and 426-432 MHz). To minimize the impact to critical Government operations, this sub-band should not be considered for Wind Profiler operations nationally.

The 430-440 MHz portion of the band currently contains the second highest number of GMF assignments. This 10 MHz band is the only spectrum allocated to the radiolocation service on a primary basis below 1 GHz worldwide. Numerous military radars and drones operate in this band. Amateur operations include satellite (435-438 MHz) and other low signal level operations on a secondary basis. As a result, the 430-440 MHz band should be avoided for Wind Profiler operations both nationally and internationally.

The 440-450 MHz portion of the band currently contains the lowest number of GMF assignments. The military has assignments for radiolocation and drone control in this sub-band. The band is used on a secondary basis by the amateurs for repeater operations at 442-450 MHz and ATV operations at 438-444 MHz. To minimize the impact to the current users of the band, two candidate frequencies have been identified, each of which has advantages and disadvantages. To minimize the impact on current military operations, a frequency near the upper band edge would be more desirable. As a result, the candidate frequency 449 (2 MHz necessary bandwidth) has been identified. By selecting 449 MHz, interactions between the profiler and military radars would be minimized as compared to selection of a frequency in the middle of the band. The disadvantage of 449 MHz is the impact to the amateurs repeater operations in the 442-450 MHz band. The other candidate frequency identified is 441 MHz. The frequency 441 MHz has certain advantages, among them are: (1) minimize the impact to amateur repeater operations in the 442-450 MHz band, and (2) Canada has adopted 441 MHz for their Wind Profiler operations. The disadvantage of 441 MHz is the larger potential impact to military operations. Although two candidate frequencies have been identified for Wind Profiler operations, only one frequency should be ultimately selected. Overall, the national EMC assessment of the 420-450 MHz band is **CONDITIONAL.**

Based on the national and international allocation and the national EMC assessments, the 420-450 MHz band is considered **CONDITIONAL,** both nationally and internationally.

Summary

Table 2-1 contains a summary of the national and international allocation and the national EMC assessments for each of the three candidate bands. The Table assesses each band in terms of Suitable, Conditional, and Unsuitable.

TABLE 2-1

ASSESSMENT OF FREQUENCY BANDS 216-225 MHz, 400.15-406 MHz, AND 420-450 MHz IN TERMS OF SUITABLE, CONDITIONAL, AND UNSUITABLE FOR POSSIBLE WIND PROFILER ACCOMMODATION

Frequency (MHz)	Allocation		EMC		Overall	
	National	International	National	International	National	International
216-225	C	U	C	-	C	U
400.15-406	C	S	U	U[a]	U	U
420-450	C	C	C	-	C	C

S - Suitable
C - Conditional
U - Unsuitable

[a] The EMC assessment for this band considered a national/international system, COSPAS/SARSAT.

CONCLUSIONS

General

The following general conclusions are based on the assessment of three candidate bands (216-225 MHz, 400.15-406 MHz, and 420-450 MHz) for possible Wind Profiler accommodation. Specifically, the conclusions are based on the assumptions, characteristics, and methods identified for the two types (Type A and B) of Wind Profilers used in the study.

1. For all Wind Profiler users to be accommodated on a primary basis, changes in the Table of Frequency Allocations would be required in any of the three frequency bands being considered for this study.

2. To date, several agencies have requested spectrum certification from NTIA for their 200-500 MHz Wind Profiler applications. Most of the Government profilers deployed to date in the 200-500 MHz band operate on an experimental basis around 404.37 MHz. None of the applications submitted have completely met the radar spectrum standards.

3. Although several users have expressed interest in Type B profilers, spectrum certification from NTIA has not been requested. Based on the Wind Profiler characteristics assumed for the study, Type B profilers have greater bandwidth requirements (4 MHz) as compared to Type A profilers (2 MHz). Type B profilers cannot be accommodated in any of the bands studied.

4. Various factors associated with Wind Profiler operations, such as performance requirements, characteristics, and number of units deployed, may vary depending on the specific user. Each one of these factors must be considered individually, as well as in combination, when analyzing compatibility with some systems.

5. Future design enhancements to Wind Profilers or siting considerations (e.g., fences or berms) may increase their compatibility with some systems.

6. If a common frequency band could be adopted both nationally and internationally for Wind Profiler operations, it may promote U.S. trade since two major manufacturers are located in the U.S.

<u>Specific Conclusions for Each Band</u>

7. **216-225 MHz BAND**: This band is considered **CONDITIONAL** for Wind Profilers, nationally, and **UNSUITABLE** internationally. Compatible operation of Wind Profilers in the 216-225 MHz band may be possible in some geographic areas of the U.S., subject to coordination and/or case-by-case EMC analysis. Based on sharing considerations, the frequency 219 MHz (2 MHz necessary bandwidth) is found to be the most suitable frequency in this range. This frequency minimizes potential interference to TV broadcast operations in the lower adjacent band and avoids sharing with the expected heavy concentration of land mobile and amateur use in the upper adjacent band. Type B profilers, due to bandwidth requirements, could not be accommodated in this band. A detailed study of the potential interference to TV-13 receivers would be required before any widespread wind profiler operations could be considered in the 216-225 MHz band. The expected expansion of the maritime mobile service in the 216-220 MHz portion also impacts sharing.

8. **400.15-406 MHz BAND:** Based on the EMC assessment, neither Type A nor Type B profilers can operate in the 400.15-406 MHz band without shutting down to prevent interference to the COSPAS/SARSAT satellites passing overhead. From a regulatory viewpoint, this shutdown is not considered to be an acceptable or effective means to ensure the necessary protection requirement for a safety-of-life service. Future enhancements to the current 404.37 MHz Wind Profiler design may improve compatibility between the Wind Profiler and COSPAS/SARSAT. However, due to the potential national and international regulatory burdens associated with, 1) developing and gaining worldwide acceptance and enforcement of spectrum and operational standards to ensure compatibility with COSPAS/SARSAT, 2) adopting interference reporting and mitigation procedures, and 3) resolving equipment malfunction and human error concerns, the EMC assessment of this band is considered **UNSUITABLE**, both nationally and internationally.

9. **420-450 MHz BAND:** The 440-450 MHz portion of the 420-450 MHz band is considered **CONDITIONAL** for Wind Profilers both nationally and internationally. To minimize the impact to current users of the band, two candidate frequencies have been identified, each of which has advantages and disadvantages to specific users. Specifically, the frequency 441 MHz (2 MHz necessary bandwidth) and 449 MHz (2 MHz necessary bandwidth) within the 440-450 MHz sub-band are identified as candidate frequencies for Wind Profilers operations nationally. Only one of these frequencies should be selected.

RECOMMENDATIONS

The following are NTIA staff recommendations based on the findings of 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 via separate correspondence modifying established rules, regulations and procedures.

1a. The sub-band 440-450 MHz should be considered for national Wind Profiler operations. Within that band, two candidate frequencies 441 MHz (2 MHz necessary bandwidth) or 449 MHz (2 MHz necessary bandwidth) should be considered nationally.

To accommodate Wind Profiler radars, a footnote should be incorporated into the National Allocations Table stating the following:

> USXXX - The frequency 44X MHz (2 MHz necessary bandwidth) is also allocated on a primary basis for both Government and non-Government operation of Wind Profiler systems, except to military airborne platforms, in which case they are secondary.

1b. Additionally, on a case-by-case basis, the frequency 219 MHz (2 MHz necessary bandwidth) should be considered for Wind Profiler operations in certain geographic locations, subject to successful coordination with authorized users of the band and consideration of the adjacent band channel TV-13 broadcast operations.

2. Type B Wind Profilers, due to the wider bandwidth requirement (4 MHz), should not be accommodated in any of the three candidate frequency bands addressed in this study.

3. NTIA, in conjunction with the FCC, should review and update, if necessary, the appropriate service rules and spectrum standards to address Wind Profiler operations.

4. NTIA should submit appropriate findings of this study for publication in international fora, such as the International Radio Consultative Committee (CCIR).

5. To ensure long term protection of the safety-of-life COSPAS/SARSAT system, current experimental Wind Profiler operations at 404.37 MHz should be phased out.

SECTION 3

WIND PROFILER SYSTEM

INTRODUCTION

Since the DOC is establishing a nationwide Wind Profiler network in the 200-500 MHz band, efforts to accommodate Wind Profilers has been focused in that band. Furthermore, most of the profilers deployed to date in the 200-500 MHz band operate on an experimental basis in the 400.15-406 MHz band, specifically at 404.37 MHz. In addition to considering the 400.15-406 MHz band, this study is evaluating two alternative bands (216-225 MHz and 420-450 MHz) for possible Wind Profiler accommodation. As a result, the Wind Profiler operational considerations for those bands must be addressed.

Based on a phone conversation with one manufacturer[3], it was determined that: (1) the assumed characteristics for Wind Profiler operations at 404.37 MHz would remain the same without impacting performance requirements in either of the two alternative candidate frequency bands (216-225 MHz and 420-450 MHz) being considered, (2) the preferred band of operation would be at 216-225 MHz since the attenuation effects would be a lesser problem than at 400 MHz, and (3) the cost of a Wind Profiler system may vary depending on the selection of the frequency band chosen for operation. For example, if the 216-225 MHz band is selected for Wind Profilers, the antenna currently being used for 404.37 MHz Wind Profiler operations would increase in price by about a factor of four.

Given below is a brief overview of the Wind Profiler operations as well as a discussion of the assumptions pertaining to this study regarding Wind Profiler deployments, characteristics, and design.

WIND PROFILER OPERATIONS

Research over the past 15 years has concentrated on three different frequencies for Wind Profiler operations, near 50 MHz, near 400 MHz, and near 900 MHz. The advantage of the lower frequencies are that they are less attenuated by precipitation and can "see" higher. However, the lower frequencies do not allow the higher resolution measurements close to the ground which are important for weather forecasting. Table 3-1 compares some typical performance characteristics at the three frequencies. Additional documentation delineating the specific operations of Wind Profilers is available in the literature.[4]

The Wind Profiler is a vertically oriented ground-based pulsed radar that utilizes scattering from irregularities in the index of refraction in the atmosphere to measure wind parameters in three dimensions (Figure 3-1). By transmitting pulses on sequential beams (e.g., east, north, and vertical) and processing the return signal, profiles of the wind can be obtained faster and cheaper than by balloons. Range gate and Doppler radar principles are applied to deduce the

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[3] G. Patrick, NTIA, Telephone Conversation with Vern Peterson, Chief Scientist, TYCHO Technology, Inc., March 13, 1990.

[4] NOAA, <u>Principles of Wind Profiler Operations</u>, Prepared for the Office of Meteorology (National Weather Service), Profiler Program NOAA/ERL Boulder, CO, March 1988.

wind parameters from signals received from each of the beam positions. By integrating the backscatter signal pulses at one beam position over a suitably long period of time (i.e., 2 minutes), it is possible to operate with very low signal-to-noise ratios (e.g., -20 dB).

The desired backscattered signals required by the Wind Profiler are very weak compared with those that would be reflected, for instance, from an aircraft passing through the beam. Because the Wind Profiler uses relatively long periods of time for integration to extract the desired return signals from the noise, any undesired returns, such as those received from reflections by aircraft or flocks of birds are usually filtered out without affecting the accuracy of the wind measurements. However, at some specific Wind Profiler locations (e.g., airports), the accuracy of the wind measurements may be affected if the profiler processes numerous momentary undesired returns for long periods of time.

TABLE 3-1
SOME TYPICAL PROPERTIES OF PROFILERS OPERATING AT COMMON FREQUENCIES

	1 GHz	**400 MHz**	**50 MHz**
Altitude Range	0.2-5 km	0.5-16 km	2-20 km
Antenna Size	3 m^2	150 m^2	10,000 m^2
Peak Power	0.5 kW	40 kW	250 kW
Beam Width	6°	4°	3°
Effect of Raindrops	Large	Moderate	Small

(The altitude range shown is representative and considerable variation can occur, depending upon meteorological conditions and operating parameters.)

These Wind Profilers will provide several useful capabilities. For example, profilers will be used to improve short and long range weather forecast, to route commercial aircraft for improved fuel efficiency, and to monitor the atmosphere for hazardous conditions prior to rocket launches. Other possible uses are for monitoring the dispersion of rocket exhausts during the tests, wind monitoring for aerostat operations and pollutant dispersal.

Although Wind Profilers may differ in design depending on the user requirements, most 200-500 MHz profilers will measure a vertical profile of the horizontal wind movements every 6 minutes. To accomplish this, the data is taken and averaged for 2 minutes (1 minute in each high and low mode) in each beam direction (east, north, and vertical). The radar "high" mode is used for measuring winds at high altitudes and a "low" mode is used for measuring winds at low altitudes. The data contained in each profile consists of the return power and radial velocity for each beam position and altitude mode. At the end of this 6 minutes, the data is transmitted over dedicated phone lines or satellite links to a computer at a center location. These six-minute profiles are considered short term. Hourly wind profiles are also generated at the central location from the transmitted 6-minute data. Using the data received in a one-hour period (10 x 6 minute profiles), a random sample consensus algorithm (4 of 10 samples) is used to produce these one-hour profiles.

In summary, profilers are sensitive Doppler radars capable of measuring winds for a variety of functions. To accomplish this, they should operate in an environment free of interference. The desired atmospheric signals the profiler must detect are continuous and very low level. The entire process to obtain profiles is susceptible to interference, since it is similar to the atmospheric signal and will be processed by the profiler as erroneous wind measurements. Continuous interference must be avoided for useful profiler operation. Low duty

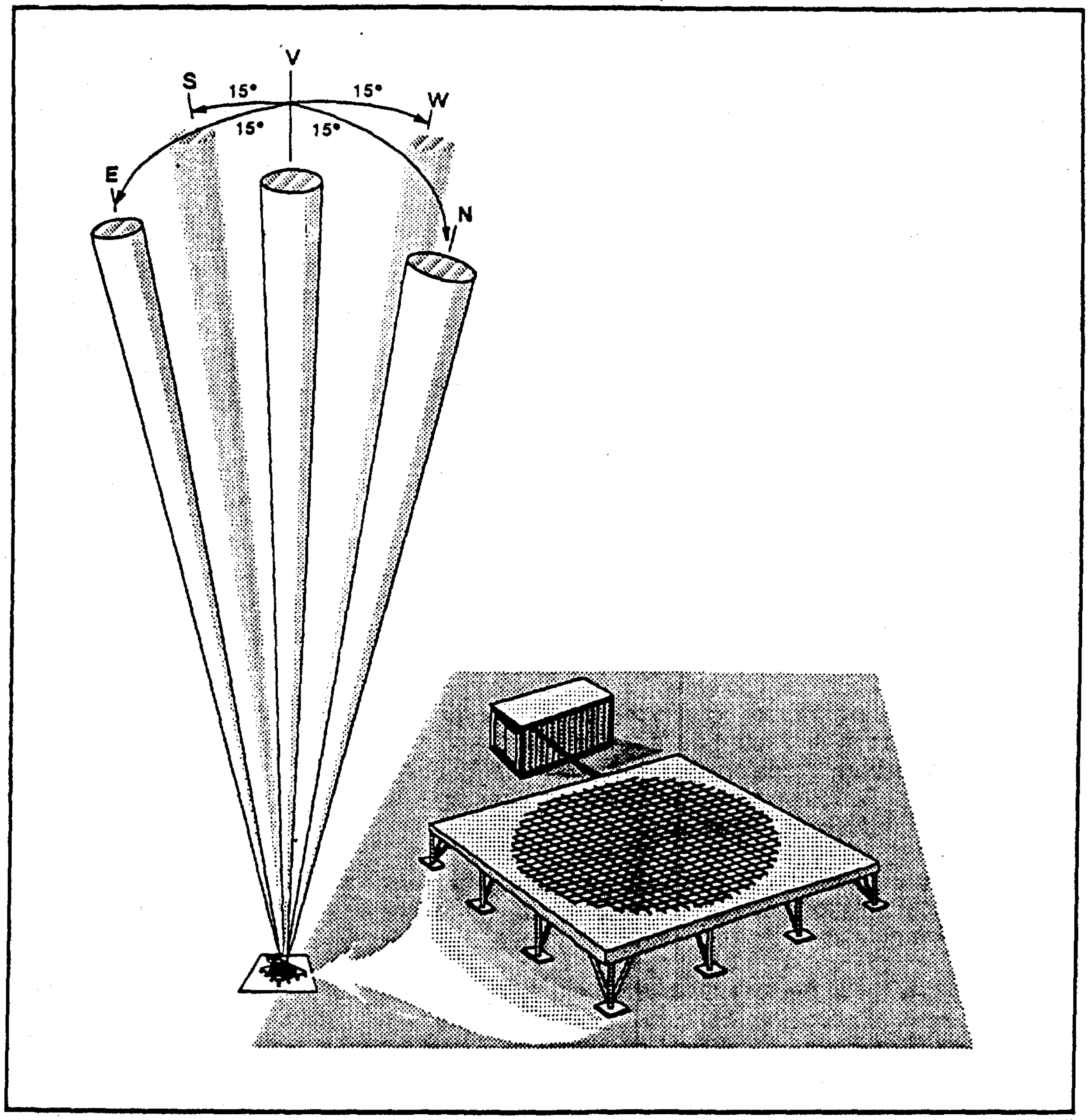

Figure 3-1. Typical beam configuration for Wind Profilers consists of three beams: one vertical, and two tilted 15 degrees from zenith (to the east and north, for example). Under some circumstances, two additional beams are needed (such as to the south and west).

cycle interference (i.e., pulsed transmissions with 1-3 interference episodes per hour) can be tolerated because only a few of the short term profiles are affected. The intermediate case of pulsed interference with many episodes per hour may degrade profiler operation depending on the level of the interference. As a result, continuous wave like interference received via direct path or indirect path coupling from fixed sources should be avoided. Pulsed interference received via direct path or indirect path coupling from sources may be tolerable depending on the level and the number of interference episodes occurring per hour. The type and amount of interference received by a Wind Profiler will vary depending on location. At the time of completion of this study, very limited measurements and/or studies have been available in the literature delineating the effects of interference on Wind Profilers operations.

In conjunction with obtaining wind profiles at various frequencies, a capability to obtain temperature profiles has been identified. Using the Radio Acoustic Sounding System (RASS) technique, temperature profiles with good time and height resolution are possible depending on the frequency of operation. The RASS is a promising method of remotely sensing temperature profilers by combining acoustic techniques utilizing signal processing capabilities of the Wind Profiler. It has been determined that the use of frequencies around or below 400 MHz would provide the most useful temperature profiles. The method to obtain temperature profiles would require an additional add-on feature to the current profiler design. Additional details on the RASS system and its capabilities are available in the literature.[5]

WIND PROFILER DEPLOYMENT

The number and types of Wind Profiler radars to be deployed nationally and internationally will vary depending on the particular user requirement. Internationally, plans for a European profiler network have been proposed; however, the specific details on the selection of various parameters such as frequency band, deployments, and characteristics of the European Wind Profiler network have not been selected. According to one manufacturer[6], a single Wind Profiler has been purchased by another country for research purposes. Nationally, several users (DOC, DoD, Treasury, and private sector) have stated their specific Wind Profiler requirements through fora such as Spectrum Planning Subcommittee (SPS) and Interdepartment Radio Advisory Committee (IRAC). Based on a review of these requirements, two distinct types of Wind Profilers are expected to be deployed nationally.

One type of Wind Profiler is to be used by the National Oceanic and Atmospheric Administration (NOAA) for weather forecasting and various meteorological studies (i.e., severe storms, pollution dispersal, etc.). In particular, this type of Wind Profiler will initially be used in a demonstration network of 30 Wind Profilers in the central part of the U.S. Figure 3-2 shows the initial deployment of the 30 NOAA Wind Profilers. It is estimated that once completed, the number of Wind Profilers in the NOAA network will range between 200 to 300 and will form a grid across the U.S. It is noted that this specific type of Wind Profiler may also be deployed by users other than NOAA (i.e., DoD).

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[5] May, P.T., Strauch, R.G., Moran, K.P., The Altitude Coverage Of Temperature Measurements Using RASS With Wind Profiler Radar, Wave Propagation Laboratory, ERL, NOAA, Boulder, Colorado, July 12, 1988.

[6] Patrick, G., NTIA and Vern Peterson, Chief Scientist, TYCHO Technology, Inc., Telephone conversation, March 26, 1990.

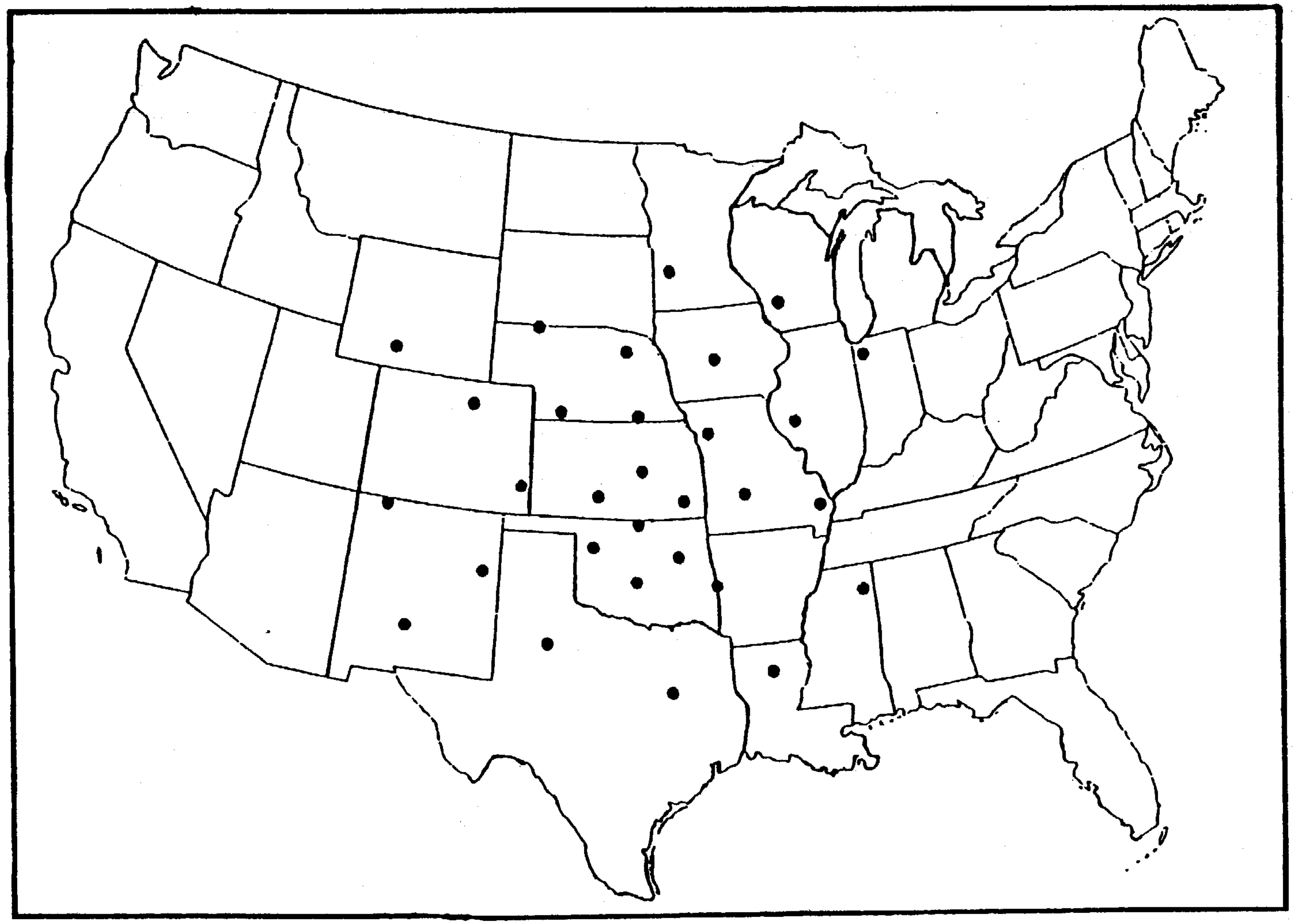

Figure 3-2. Locations of Initial 30 Wind Profilers to be deployed for the NOAA demonstration network.

A second type of Wind Profiler identified for national use will be a less complex version of the "NOAA Type" Wind Profiler with less altitude range (approximately 5-7 km compared to 15-20 km) coverage. This specific type of Wind Profiler will be used in operations such as Aerostat control, forest fire control, smog prediction, etc. The expected deployment and total numbers of these types of Wind Profilers are unknown. The U.S. Customs Service has expressed interest in deploying this particular type of profiler at six specific locations in the U.S. to aid in the operations of Aerostats.[7] In addition, Penn State University has a similar type of profiler deployed for research purposes. The assumed characteristics identified for both types of Wind Profilers are given in the following sub-section.

WIND PROFILER CHARACTERISTICS

Based on (1) applications that have been received for national spectrum support through the SPS, and (2) documentation received in the IRAC, two distinct types of Wind Profilers were identified for the study. Discussed below is the method in which the characteristics for each type of profiler was obtained.

The DOC has requested and been granted Stage 2 spectrum support for experimental operation of its Wind Profiler on 404.37 MHz. This particular profiler will be operated continuously and will be used in the NOAA experimental network initially consisting of 30 profilers (Figure 3-2) with the total number expected to reach approximately 200-300. In addition, the Navy requested and has been granted Stage 2 spectrum support for experimental operation of its Wind Profiler on 404.37 MHz. The Navy's Wind Profiler will be used for post graduate school meteorological efforts at Ft. Ord, CA.

The Wind Profilers to be used by both NOAA and Navy are similar since they will provide approximately 15-20 km range coverage; however, the designs of the two systems are different. For example, the NOAA Wind Profiler contains techniques, such as using minimum-shift keying (MSK) modulation, which makes it potentially more compatible with other systems. It is assumed that the Wind Profiler used by NOAA in the national network will represent a distinct type since there will be a large number deployed by NOAA and potentially other users. The deployed cost of this distinct type of profiler is approximately $500,000 for a single unit. The characteristics given in TABLE 3-2 are assumed to represent a typical NOAA Wind Profiler and were extracted from several sources such as SPS submissions, test measurement data, phone conversations with manufacturers, and data contained in the literature. To date, there have been no radiated test measurements to verify all the characteristics given in TABLE 3-2 that represent this specific type of Wind Profiler. This type of Wind Profiler will herein be referred to as Type A. The actual characteristics to represent a deployed NOAA profiler will be similar to those stated in TABLE 3-2. Some specific characteristics associated with the Type A profiler are discussed below.

The antenna to be used for the Type A Wind Profiler is a co-linear coaxial (COCO) type allowing high directivity in one direction. Specifically, the COCO antenna is made up of individual radiating elements. Each element is similar to a standard dipole antenna. By placing many of these dipole elements parallel and orthogonal to each other, a large-aperture antenna array is obtained. The COCO type antenna to be used for Type A profilers is a resonant coaxial

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[7] FAS Chairman, "Wind Profiler Radar," IRAC Doc. 26789/1-4.16/2.3.2, April 4, 1990.

structure and is inherently narrow band. According to the manufacturer[8], the far-out spectral energy is attenuated equivalent to a 7-pole bandpass filter with a 3 dB point at approximately 4 MHz away from resonance.

The transmitted pulses in Type A are phase modulated with a MSK waveform and pseudo random bit stream to reduce spectral sideband levels. In the high mode, there are three MSK symbols or chips per pulse, and in the low mode, there are two chips per pulse. Figure 3-3 shows the spectra of the transmitted signal out to 4 MHz for frequencies above the carrier; estimates have been made for spectral density at frequencies removed farther away from the carrier.

The antenna pattern for the Type A profiler, especially at large off axis angles from the mainbeam, is important in analyzing potential interference. To determine the off axis gain values, UNISYS conducted near-field measurements and used them to estimate the far-field gain values for each beam position.[9] The values obtained by UNISYS were further processed to determine the average gain level as a function of elevation angle gain for all beam positions.[10] The average antenna gain values contained in TABLE 3-2 represent the interpolated values from Reference 10 for off axis values between 15 and 90 degrees. A draft document available in the literature was used to determine the average off axis antenna gain value between 2.5 and 15 degrees.[11]

The characteristics assumed to represent the second distinct type of Wind Profiler were determined from several sources. Initially, this type of profiler was requested by the U.S. Customs Service, through the IRAC, to provide support of its Aerostat operations along the southern border of the U.S. and ultimately in the Caribbean area. However, the characteristics specified for this type of Wind Profiler (Reference 7) were insufficient for this study. One manufacturer indicated that a similar type of profiler is currently being used to support the atmospheric field program at the San Joaquin Valley Air Pollution Study Program, a program cosponsored by both the private sector and several state and local governments, and for the Penn State University. It was determined that the characteristics provided by the manufacturer[12] for this type of Wind Profiler represented similar characteristics to those stated for the U.S.

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[8] Hudson, E.F., UNISYS, "BANDWIDTH," MEMORANDUM TO: Dr. Hans Richner, Atmospheric Physics ETH (LAPETH), Zurich, Switzerland, March 31, 1990.

[9] Unisys (1988), "Wind Profiler Antenna Test Report," Contract No. NA-86-QA-C-101, July, 1988.

[10] Chadwick, R.B., SARSAT Interference Potential for Alaska Profiler Network, Profiler Program Office, Environmental Research Laboratories, May 24, 1990.

[11] Sullivan, T., Wolf, D., Potential Interference From Wind Profiler Radars to the COSPAS/SARSAT System (Draft), Atlantic Research Corp. (for NOAA/NESDIS), USSG 8C-303 (Rev-1), July 22, 1990.

[12] Peterson, Vern, Chief Scientist, TYCHO Technology, Inc., "TYCHO Parameters," Fax Correspondence, May 16, 1990.

Customs Wind Profiler. These characteristics, given in Table 3-2[13], were used to represent the second type of profiler, herein referred to as Type B. To date there have been no radiated test measurements to verify all the characteristics given in Table 3-2 that represent this type of Wind Profiler.

This second type of Wind Profiler is a less costly, less complex version as compared with the first type (Type A). For example, the altitude range coverage of this type of profiler is approximately 5-7 km with a peak power output of 800 Watts (59 dBm) compared to the 15-20 km altitude range coverage and a peak power output of 16 kW for Type A. Currently, Type B profilers do not use MSK and pseudo random bit stream to potentially reduce spectral sidelobe levels. Although the requirements and characteristics for this type of Wind Profiler are different from those given for Type A, the process to obtain and generate wind profiles would be similar. The cost of this second type of Wind Profiler is approximately $150,000 as compared to approximately $500,000 for Type A. Spectrum certification from NTIA for this type of Wind Profiler has not been requested.

[13] The colinear coaxial (COCO) antenna for the Type B profiler is assumed to have the same properties as given for Type A (i.e., equivalent to 7-pole bandpass filter with a 3 dB point at approximately 4 MHz from resonance).

TABLE 3-2
ASSUMED CHARACTERISTICS FOR A & B TYPE PROFILERS

	TYPE A		TYPE B	
	High Mode	Low Mode	High Mode	Low Mode
Frequency (MHz)	404.37	404.37	404.37	404.37
Peak Transmitter Power (dBm)	72	69	59	59
Average Transmitter Power(dBm)	63.1	54.2	45.2	40.5
PRF (pulses per second)	6500	10,000	11000 pps	14,000 pps
Chip Width (μs)	6.67	1.67	n/a	n/a
Pulse Width (μs)	20	3.35	3	1
Pulse Duty Factor (%)	13	3.3	3.3	4.1
Mainbeam Gain (dBi)	32	32	27	27
Antenna Halfpower Beamwidth (deg.)	5	5	8	8
Antenna Type	Co-Linear Coaxial	Co-Linear Coaxial	Co-Linear Coaxial	Co-Linear Coaxial
Antenna Beam Elevation Angle (Alternating, East, North, Vertical)	90, 75 deg	90,75 deg	90,75 deg	90,75 deg
Antenna Polarization	Linear	Linear	Linear	Linear
Noise Level (dBm)	-124.9	-120.2	-110	-110
Emission Spectra[a]	Figure 3-3	Figure 3-3	Figure 3-5	Figure 3-5
IF Selectivity Response	Figure 3-4	Figure 3-4	Figure 3-6	Figure 3-6
Average Antenna Off Axis Gain Values:				
	Angle Range (deg)	Gain (dBi)	Angle Range (deg)	Gain (dBi)
	0-2.5	32	0-4	27
	2.5-15	10.7	4-15	5
	15-30	0	15-30	2
	30-60	-10	30-60	-4
	60-90	-20	60-90	-13
	[85-90][b]	-25	[85-90][b]	-20

[a] The emission spectra are assumed to be symmetrical about the carrier.

[b] The average gain at elevation angles near the horizon (less than 5 degrees, or antenna off-axis angles greater than 85 degrees) is on the order of -25 dBi and -20 dBi for Type A and Type B profiles, respectively. These are the values used for determining compatibility with surface systems.

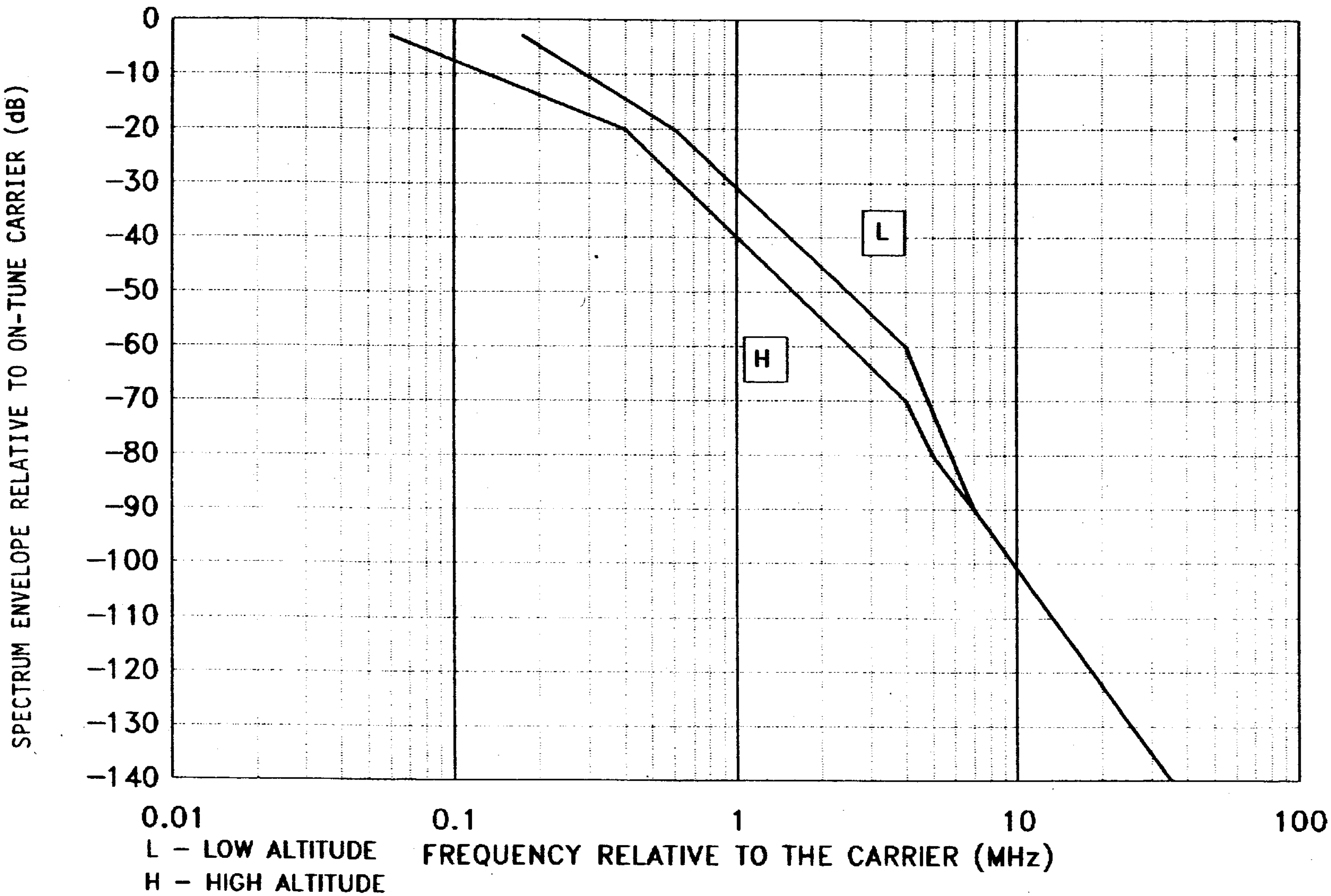

Figure 3-3. Type A Wind Profiler Emission Spectra.

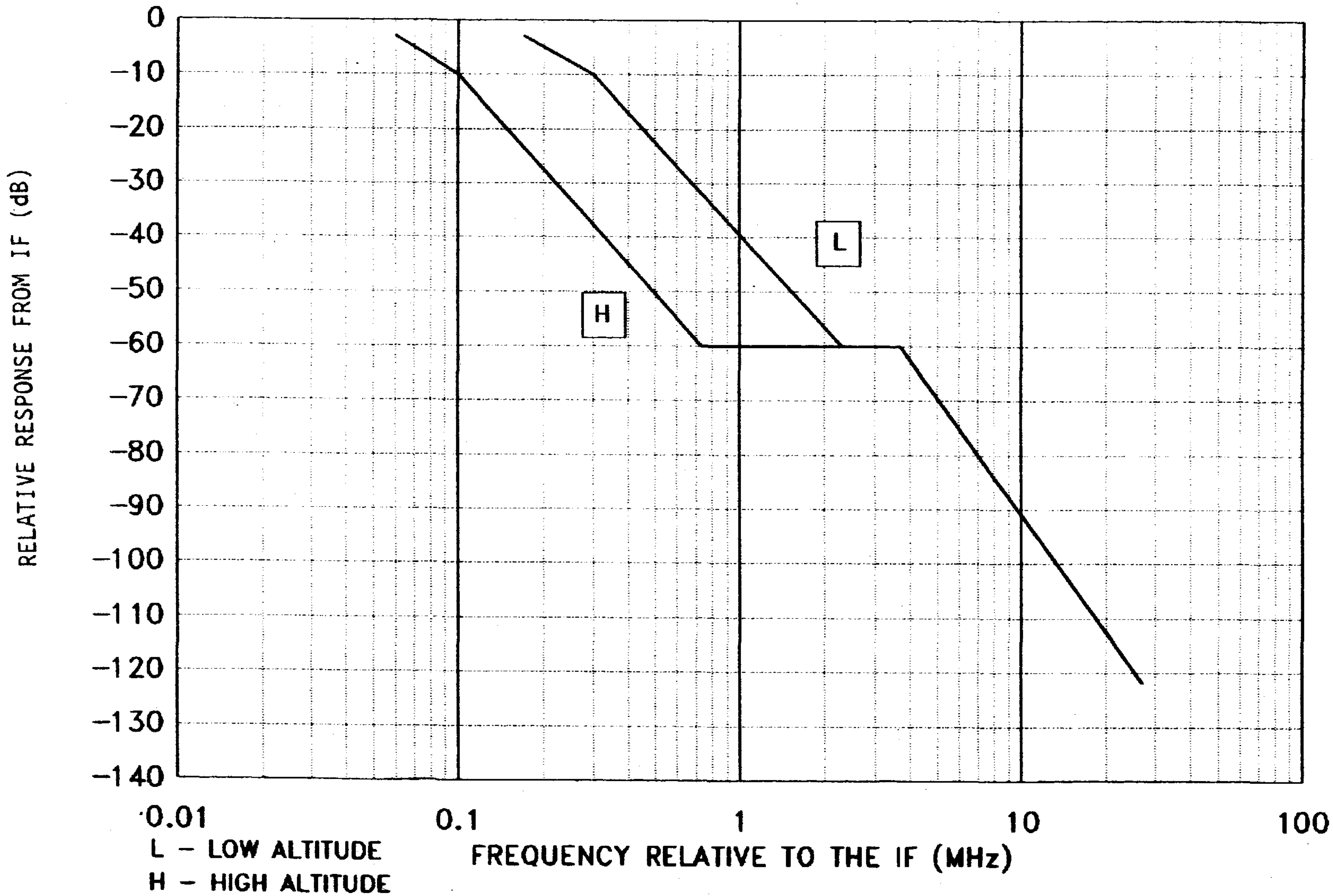

Figure 3-4. Type A Wind Profiler Selectivity.

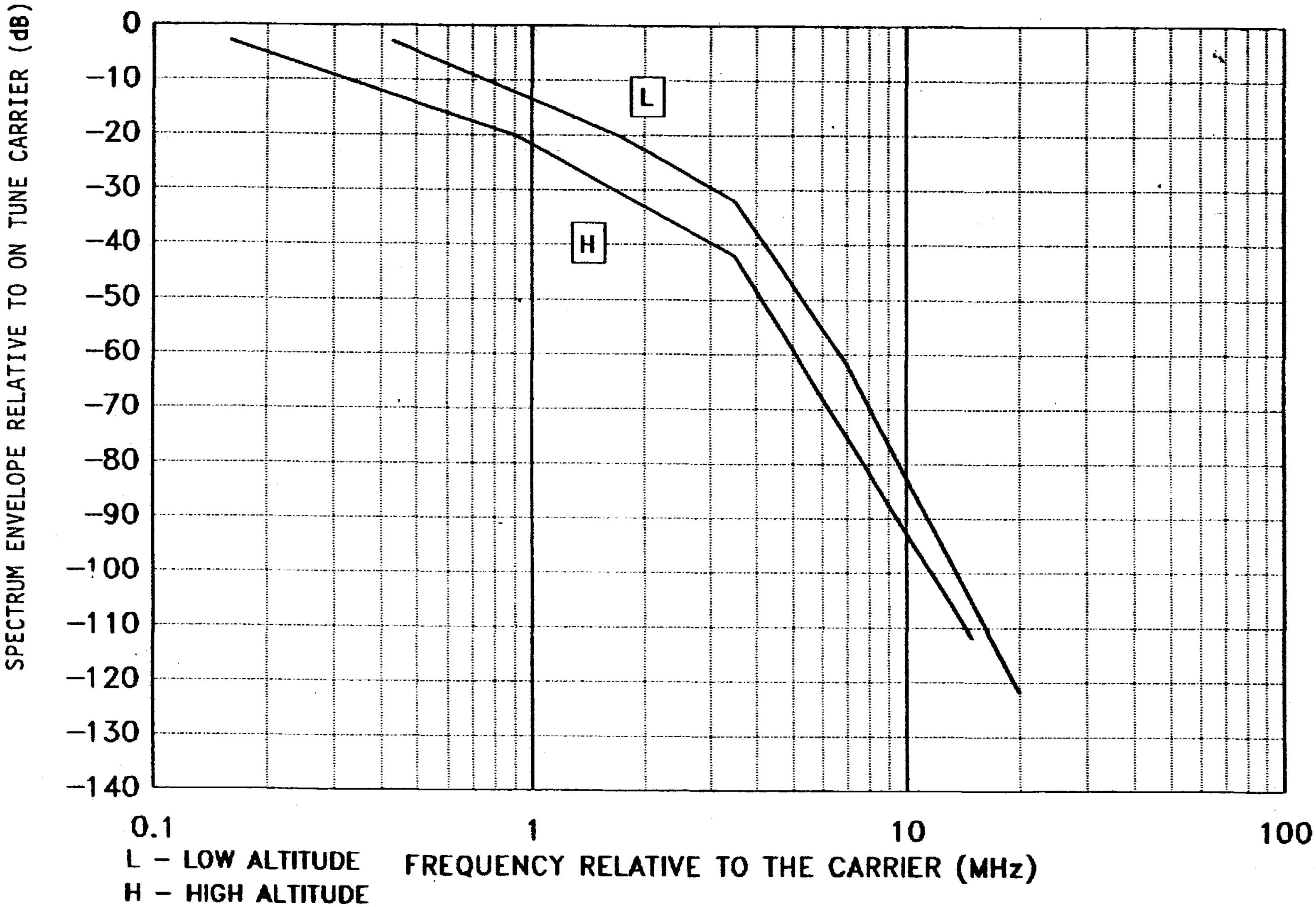

Figure 3-5. Type B Wind Profiler Emission Spectra.

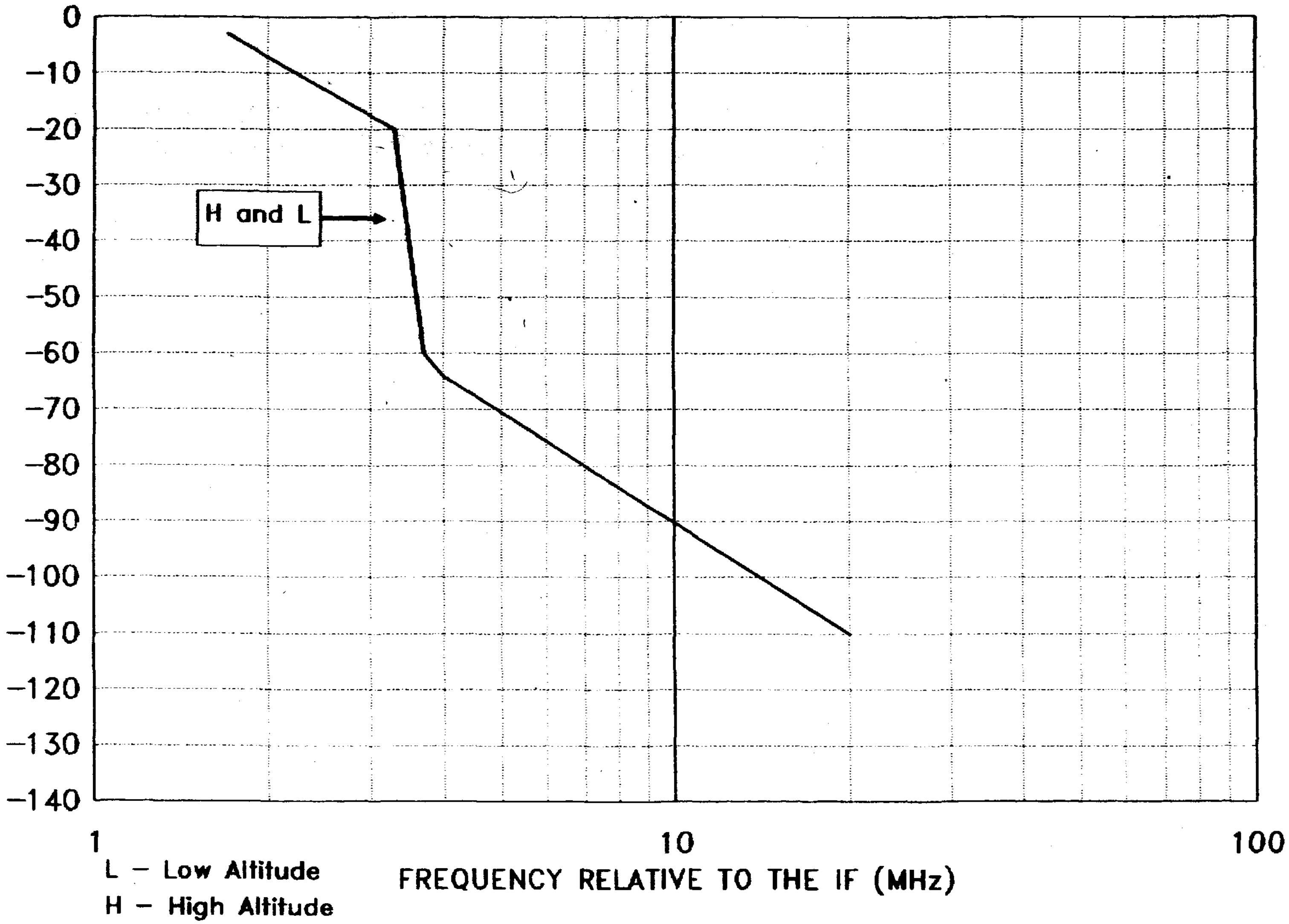

Figure 3-6. Type B Wind Profiler Selectivity.

WIND PROFILER DESIGN

Currently, Wind Profilers operating on 404.37 MHz have a potential to interfere with the COSPAS/SARSAT satellite which is a safety-of-life system. In attempting to preclude potential interference with the COSPAS/SARSAT from 404.37 MHz emissions, various enhancements were investigated and incorporated into some of the Wind Profiler designs. Specifically, various enhancement features have been incorporated into the "NOAA Type" Wind Profiler, Type A. These enhancements include:

1. Low sidelobe antenna
2. Controlled rise time transmitted pulse
3. Resonant antenna
4. Minimum shift keyed (MSK) signaling
5. Phase coding to decrease signal periodicity
6. Inhibit the transmitted signal when the COSPAS/SARSAT satellite is within approximately ± 30 degrees of the profiler vertical mainbeam.[14]

Item 6 of this list regarding the shut down of the Wind Profiler is the most important factor for precluding interference to the COSPAS/SARSAT satellite. This shut down occurs when the COSPAS/SARSAT satellite is within approximately ± 30 degrees of the profiler vertical mainbeam and is controlled by computer software. In addition, this shut down does not have an effect on the performance objective of the Wind Profiler users. Although this shut down may be controlled on a national basis, it is uncertain if similar procedures would be followed by other administrations. Without these features the COSPAS/SARSAT safety-of-life service may be at risk. For example, a U.S.-manufactured Wind Profiler, having the computer software techniques necessary to shutdown as the COSPAS/SARSAT satellite passes overhead, was purchased by another administration. Indications are that these shutdown techniques are not being used.

Utilizing the majority of these enhancements to the "NOAA Type Wind Profiler" (Type A), test measurements were conducted at the Goddard Space Flight Center in Greenbelt, MD[15] to determine the impact as a result of incorporating the aforementioned enhancements to the Wind Profiler deployed at Platteville, CO. The results of the test measurements indicated that the Wind Profiler's radiated emission was noticeable in the SARSAT receiver when the satellite was in close proximity of the Profiler's mainbeam. As a result, it was determined that the Wind Profiler must continue to shut down to preclude interference when the COSPAS/SARSAT is within the profiler's mainbeam.

In the future, additional enhancements to 404.37 MHz Wind Profiler design, as well as implementing siting factor considerations (i.e., fence, berm), may increase the compatibility with COSPAS/SARSAT and other systems. However, it is noted that any additional changes to existing 404.37 MHz Wind Profilers must address not only elimination of potential interference to the COSPAS/SARSAT but must take into consideration other factors such as:

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[14] This inhibit feature is assumed to be incorporated in all the various types of Wind Profilers deployed nationally at approximately 404.37 MHz.

[15] Sessions, W.B., Boyd, B.A. Measurements of Interference in the SARSAT 406 MHz Band Due to Wind Profiler Radars, Westinghouse Electric Corporation for National Aeronautics and Space Administration, May 11, 1990.

1. Cost
2. Performance Objectives
3. Number of Wind Profilers
4. Deployment of Profilers
5. Effects of Single versus Aggregate (both mainbeam and sidelobes)
6. Effects on other Satellites operating in the 400.15-406 MHz band (e.g., SARSAT receiver on the Geostationary Orbiting Exploration Satellite (GOES), ARGOS (401.65 MHz), and Data Collection Platforms (DCP's)
7. Effects on profiler operations from other systems
8. Time to implement

SUMMARY

Various factors associated with Wind Profilers operations such as performance, design requirements, characteristics, and number of units deployed, may vary depending on the specific user. Consideration must be given to each one of these factors individually, as well as the combination of these factors when analyzing compatibility with other systems.

In addition to the two types of Wind Profilers identified for the study, "other" types of Wind Profilers may be deployed as "one of a kind" or in multiple numbers. Those types of Wind Profilers may have varying characteristics regarding compatibility from those assumed for this study or may incorporate modifications to existing designs. Furthermore, some types of Wind Profilers may employ additional siting factors techniques (i.e., berm or fence) to potentially enhance compatibility with other systems. These "other" types of Wind Profilers are not considered in this report and should be considered on a case-by-case basis.

SECTION 4

CONFORMANCE TO RADIO REGULATIONS

INTRODUCTION

This section addresses the Wind Profiler's conformance to applicable rules and regulations (i.e., the Tables of Frequency Allocations, and technical standards) for operations in the bands 216-225 MHz, 400.15-406 MHz, and 420-450 MHz. International rules and regulations are addressed, in addition to applicable U.S. national rules and regulations, to identify existing provisions and potential problem areas for worldwide profiler deployments. The Wind Profiler is assumed to require accommodation on a primary basis, nationally for all users with consideration worldwide. However, for some agency requirements, secondary status may be acceptable. Since the Wind Profiler is a radar used primarily for weather prediction, it was considered as either a radiolocation station (station class LR) or as a meteorological radar station (station class WXD).

UNITED STATES - CANADA COORDINATION AGREEMENT

Wind Profiler deployment near the United States - Canada border in either of the bands 216-225 MHz or 420-450 MHz will require coordination with Canada prior to operation. Part 3.4 of the NTIA Manual contains the United States-Canada Coordination Agreement. Section 3.4.1 provides general information on the agreement and a table denoting the bands coordinated between IRAC, NTIA and Canadian Department of Communications (CDC). Section 3.4.2 is the Index to the Technical Annex which indicates for each of the five arrangements the frequency bands involved and the authorized coordination agencies or channels in each country for each band. In the frequency range 216-225 MHz, Joint Chiefs of Staff (JCS) is the coordination agency for the U.S. and Chief of Defense Staff (CDS) is the coordination agency for Canada. Arrangement C (Section 3.4.5) applies in this band. Paragraph (1) states, "It is agreed that coordination shall be effected in those frequency bands used by fixed installation radars, some of which are essential to the defence of North America, whenever there is considered to be a likelihood of harmful interference." In the frequency range 406.1-430 MHz, NTIA and the Department of Communications are the coordination agencies. Paragraph 6.6 of Arrangement E states, "Except for the state of Alaska, any future fixed installation radiolocation system proposed for United States operation within 250 km of the United States-Canada border which would normally operate in the 420-430 MHz band will be subject to prior coordination with Canada." In the band 420-450 MHz, JCS and CDS are the coordination agencies. Arrangement C applies to this band.

FREQUENCY ALLOCATIONS

In the following discussions, the conformance of the Wind Profiler operations to the Tables of Frequency Allocations[16] in the three bands is presented and possible changes necessary to accommodate profiler operations are identified. An assessment of Suitable,

[16] NTIA, Manual of Regulations and Procedures for Federal Radio Frequency Management, U.S. Department of Commerce, National Telecommunications and Information Administration, Washington, D.C., Revised January 1990.

Conditional, or Unsuitable is given regarding the potential national and international accommodation of Wind Profiler operations for each of the three frequency bands.

The only allocation change to the National Table of Frequency Allocations that was considered for this assessment was for the 216-225 MHz band. Other factors such as WARC-92 proposals and other pending FCC and NTIA allocation changes were not considered since they had not been approved at the initiation of this study.

216-225 MHz Band

Nationally, the frequency range 216-225 MHz is divided into three allocation bands: 216-220 MHz, 220-222 MHz, and 222-225 MHz. Internationally, this frequency range falls within two allocation bands: 174-223 MHz and 223-230 MHz (in Regions 1 and 3), and 216-220 MHz and 220-225 MHz in Region 2. The allocated services in the band 216-225 MHz are shown in TABLE 4-1, an excerpt of the National and International Tables of Frequency Allocations. The allocated services shown in TABLE 4-1 for the United States in bands 220-222 MHz and 222-225 MHz reflect allocation changes per IRAC Doc. 26106. The applicable footnotes to the allocation table are provided in Appendix A. The frequency range 216-225 MHz is allocated to a variety of services on different bases (i.e., primary and secondary) and on various conditions. The radiolocation service is allocated on a secondary basis in Region 2 and nationally radiolocation is limited to the military (Footnote G2); however, this allocation applies to only stations authorized prior to 1 January 1990 (Footnote RR627). Additional allocations for radiolocation are in the Radio Regulations footnotes.

To accommodate Wind Profilers, nationally, a change to the National Tables of Frequency Allocations would be necessary. The meteorological aids service would have to be added on a primary basis or the radiolocation service changed to primary status and Footnote G2 modified for this band. Alternatively, provision for Wind Profiler operations could be made by an additional US footnote. A national allocation accommodation would involve an NTIA decision and a FCC rulemaking proceeding which include involvement from many interested parties (e.g., land mobile, maritime mobile, amateur, and adjacent band broadcasters). The Notice of Proposed Rulemaking (NPRM) proceedings dealing with the maritime mobile service may also impact Wind Profiler accommodations. As a result of WARC-79, the primary radiolocation service allocation was reduced to secondary status and the footnote RR627 was introduced for Region 2 of the Allocation Table. The addition of footnote RR627 to the Allocation Table does not allow new radiolocation systems to operate in Region 2 after January 1, 1990. The Wind Profiler would be difficult to accommodate, since the radiolocation service has been removed from the Table with the exception of existing radar systems. The national allocation accommodation of Wind Profiler operations is assessed as conditional.

Internationally, for Wind Profilers to be accommodated on a primary basis in this band, the meteorological aids service would have to be added to the international table or the radiolocation service upgraded in Region 2. In Regions 1 and 3, the meteorological aids or radiolocation service would have to be added in the allocation band 174-223 MHz. Accommodation by international footnote is also an option. These allocation changes would involve acceptance at a future WARC. Due to the diverse provisions of the current international table among the different regions, the present primary allocation to the broadcasting service in Regions 1 and 3, and the number of existing exceptions to the current table, the international accommodation of Wind Profiler is assessed as unsuitable in the bands 216-225 MHz.

TABLE 4-1
EXCERPTS FROM THE INTERNATIONAL AND NATIONAL TABLES OF FREQUENCY ALLOCATIONS FOR THE BAND 216-225 MHz

INTERNATIONAL			UNITED STATES			
Region 1	Region 2	Region 3	Band MHz	Prov.	Gov.	Non-Gov
174-223 BROAD- CASTING	174-216 BROAD- CASTING Fixed Mobile 620	174-223 FIXED MOBILE BROAD- CASTING	174-216			BROAD- CASTING (tele- vision) NG115
621 623 628 629	216-220 FIXED MARITIME MOBILE Radio- location 627 627A	619 624 625 626 630	216-220	US210 US229 US274 627	MARITIME MOBILE Radio- location Fixed Aero- nautical Mobile Land Mob G2	MARITIME MOBILE Fixed Land Mobile Aero- nautical Mobile NG121
223-230 BROAD- CASTING Fixed Mobile	220-225 AMATEUR FIXED MOBILE Radio- location 627	223-230 FIXED MOBILE BROAD- CASTING AERONAUTICAL RADIONAV- IGATION Radiolocation 636 637	220-222	US243 627	LAND MOBILE Radio- location G2	LAND MOBILE
622 628 629 631 632 633 634 635			222-225	US243 627	Radio- location G2	AMATEUR