SECTION 6

ELECTROMAGNETIC COMPATIBILITY

INTRODUCTION

For the frequency ranges 216-225 MHz, 400.15-406 MHz and 420-450 MHz, an EMC analysis between Type A and B Wind Profilers and various environmental systems (Government and non-Government) was performed. The assumptions and characteristics for each type of profiler are given in Section 3. Details of the parameters pertaining to the systems selected are given as they are encountered in this section. .

To determine EMC in the 216-225 MHz and 420-450 MHz bands, frequency-distance (F-D) curves were generated between each of the two types of Wind Profilers and each of the environmental systems identified. A discussion of the method used to create F-D curves is given in Appendix B. A number of assumptions concerning equipment parameters were used in assessing EMC. For example, when the parameters of systems were similar, a typical system was used to represent all the systems in a class of related types; when system parameters and equipment vary widely, only major systems were considered. In addition, some services/systems were excluded from the study for various reasons, which are discussed. Although the answers obtained may not be a final quantitative result, they are useful in evaluating the relative EMC potential of Wind Profiler operations with the various systems or classes of systems considered. No experimental assignments were considered for the study.

F-D curves were generated using an Interference-to-Noise Ratio (INR) approach assuming the coupling between a single Wind Profiler and each environmental system identified from the 216-225 MHz or 420-450 MHz bands. The environmental systems were categorized into two types, surface and airborne. For surface systems, the Wind Profiler 85-90 degree off-axis antenna gain values (-25 dBi and -20 dBi for Type A and B, respectively) were used. For airborne systems, the Wind Profilers 60 to 90 degree off-axis antenna gain values (-20 dBi and -13 dBi for Type A and B, respectively) were used. These values represent the antenna coupling most expected to occur between Wind Profilers and environmental systems. Additional assumptions for the 216-225 MHz and 420-450 MHz study are given in Appendix B.

The results shown in Appendix B provide the frequency-distance separations necessary to preclude interference between each type of Wind Profiler and selected environmental systems in the 216-225 MHz and 420-450 MHz bands. The actual frequency and distance separations may be smaller when factors such as signal processing and terrain are considered. In addition, time sharing may be an alternative solution when F-D separation is not possible, if 24 hour operation of the profiler is not necessary. Although these factors are not included in the study to obtain the F-D values, they are considered when addressing the suitability of the band for possible Wind Profiler accommodation.

To determine the EMC in the 400.15-406 MHz band, a different approach was taken. The only system considered was the COSPAS/SARSAT, which operates in the upper adjacent band 406-406.1 MHz. Both single and aggregate effects of Wind Profiler emissions on the COSPAS/SARSAT were assessed. Details of the approach as well as the various assumptions are discussed within.

As was the case for the other assessment categories in this study, the final results of the EMC assessment were assigned one of three ratings to each class of equipment: Suitable, Conditional, or Unsuitable. In assigning these ratings, various factors such as F-D curves, INR values, deployment, number, and type of platform were considered.

BAND I: 216-225 MHz

216-220 MHz Band

TABLES 6-1 and 6-2 below show the services considered for the EMC analysis and the characteristics assumed to represent each service or system.

GOVERNMENT SYSTEMS

The major Government systems in this band are surface mobile telemetry systems used for seismology, land mobile and the Navy SPASUR system used to track satellites. The telemetry systems were selected because of their number and distribution throughout the band. The technical parameters for these telemetry systems vary only slightly; therefore, the systems are treated as a class. There are a few fixed assignments also used for seismology with parameters similar to those of the surface telemetry systems. The fixed systems were not studied separately due to their relatively low number of assignments and similar characteristics to the mobile telemetry assignments; however, the results of the analysis with surface telemetry assignments should be valid for the fixed systems. The SPASUR system was selected because of the protected status of the system and its uniqueness compared to other systems in the band. The maritime mobile and aeronautical mobile services were not considered because there are no maritime mobile assignments and only five aeronautical mobile assignments with secondary status. The F-D curves are shown in Appendix B.

Government Telemetry

Generally small frequency and distance separations are necessary to preclude potential interactions between Type A and B profiler and telemetry systems. For co-channel operations, distance separations of 10 km are necessary.

TABLE 6-1
SERVICES CONSIDERED FOR EMC WITH WIND PROFILERS

SERVICES	GOVERNMENT	NON-GOVERNMENT
MARITIME MOBILE	No	Yes
Radiolocation	Yes (SPASUR only)	N.A.
Fixed	No	No
Land Mobile	Yes	Yes
Aeronautical Mobile	No	No

TABLE 6-2
ASSUMED CHARACTERISTICS FOR SYSTEMS IN THE 216-220 MHz BAND

	Maritime Mobile	Land Mobile	Surface Telemetry	SPASUR
Power	53 dBm	53 dBm	33 dBm	88.8 dBm
Emission Designator	16K0F3E	16K0F3E	16K0F2D	2H00N0N
Antenna Gain	3 dBi	3 dBi	3 dBi	13 dB (SL)
Emission Curve	-3 dB 3 kHz -20 dB 16 kHz -40 dB 18 kHz -60 dB 25 kHz	-3 dB 3 kHz -20 dB 16 kHz -40 dB 18 kHz -60 dB 25 kHz	-3 dB 3 kHz -20 dB 16 kHz -70 dB 30 kHz	-3 dB 0.4 Hz -20 dB 2.0 Hz -40 dB 10 Hz -60 dB 20 Hz
IF Selectivity Curve	-3 dB 16 kHz -20 dB 25 kHz -40 dB 28 kHz -60 dB 32 kHz	-3 dB 16 kHz -20 dB 25 kHz -40 dB 28 kHz -60 dB 32 kHz	-3 dB 16 kHz -20 dB 25 kHz -60 dB 32 kHz	-3 dB 30 kHz -20 dB 32 kHz -60 dB 36 kHz
Noise Level	-120 dBm	-120 dBm	-120 dBm	-131 dBm
Antenna Type	Vertical collinear	Vertical collinear	Yagi	Linear Phased Array
Antenna Height	30 meters	30 meters	2 meters	2 meters

Government Land Mobile

Distance separations of 40 km are necessary to preclude potential co-channel interactions between Type A and B profilers and land mobile systems.

Navy SPASUR

Distance separations of 170 km are necessary to preclude potential co-channel interactions between Type A and B profilers and the SPASUR. The SPASUR has only three transmitter locations and six receiver locations; therefore, frequency or distance separation would normally preclude interference. Since Wind Profilers and SPASUR both orient their beams vertically, sidelobe-to-sidelobe coupling was used to obtain these results.

NON-GOVERNMENT SYSTEMS

The major systems considered in this band are in the mobile service, (i.e., maritime, surface telemetry and land mobile). A typical system was used to represent each class since the parameters do not vary widely. Since the parameters of non-government telemetry and land mobile systems are similar to government systems, the same typical systems were used. In the lower adjacent band 210-216 MHz, TV channel 13 operates throughout the country with the heaviest concentration of stations in the eastern half of the country. A study of potential interactions between Wind Profilers and TV receivers was not addressed in this study. A detailed study of the potential interference to TV-13 receivers would be necessary before widespread Wind Profiler operations could be considered in the 216-220 MHz band.

Non-Government Telemetry

The parameters of a non-Government telemetry system are assumed to be the same as a Government system, thus, co-channel distance separations of 10 km are necessary to preclude interference for Type A and B profilers.

Non-Government Land Mobile and Maritime Mobile

The parameters of a maritime mobile system are assumed to be similar to that of a Government or non-Government land mobile system. The frequency and distance separations necessary to preclude potential interactions between Type A and B profilers and land mobile and maritime mobile systems are small. For co-channel operation, distance separations of 40 km would be required.

220-225 MHz Band

TABLES 6-3 and 6-4 show the services considered for the EMC analysis and the characteristics assumed to represent each service or system.

TABLE 6-3
SERVICES CONSIDERED FOR EMC WITH WIND PROFILERS

SERVICES	GOVERNMENT	NON-GOVERNMENT
	220-222 MHz Band	
LAND MOBILE	No	No
Radiolocation	No	N.A.
	222-225 MHz Band	
Radiolocation	No	No
AMATEUR	N.A.	Yes (Repeaters only)

TABLE 6-4
ASSUMED CHARACTERISTICS FOR SYSTEMS IN THE 220-225 MHz BAND

	AN/GRC-103	Amateur Repeater
Power	44 dBm	50 dBm
Emission Designator	750K00F9W	16K0F3E
Antenna Gain	12 dBi	9 dBi
Emission Curve	-3 dB 0.65 MHz -20 dB 0.75 MHz -60 dB 3.50 MHz	-3 dB 16 kHz -20 dB 20 kHz -40 dB 26 kHz -60 dB 30 kHz
IF Selectivity Curve	-3 dB 0.75 MHz -20 dB 2 MHz -60 dB 4.2 MHz	-3 dB 16 kHz -20 dB 20 kHz -40 dB 26 kHz -60 dB 30 kHz
Noise Level	-110 dBm	-120 dBm
Antenna Type	Corner Reflector	Vertical collinear
Antenna Height	2 meters	60 meters

GOVERNMENT SYSTEMS

In this band, the Army's AN/GRC-103 fixed point-to-point communication system is the only major system identified. Due to the change in the Allocation Table, the 220-222 MHz band will be used for narrow-band land mobile operations and existing radiolocation operations. In the 222-225 MHz band, only existing radiolocation will be allocated. The radiolocation service was not considered in this study because of no assignments. There are currently no land mobile assignments in the 220-222 MHz band.

Army Fixed AN/GRC-103 Communication System

The required distance separation necessary to preclude potential interactions between Type A and B profilers and the AN/GRC-103 is 30 km for co-channel operations. To preclude potential interactions between Wind Profilers and the AN/GRC-103, frequency coordination may be the most effective way to promote compatibility, since the AN/GRC-103 is capable of operating on any frequency in the band.

NON-GOVERNMENT SYSTEMS

In this frequency range, the Amateurs currently operate throughout the band on a primary basis. The Amateurs have several different operations (see Section 5). As a result of the FCC change to the Allocation Table, the band will be used for narrow-band land mobile operations in the 220-222 MHz. The 222-225 MHz portion of the band will continue to be allocated to the amateur service. There are currently no land mobile assignments in the 222-225 band.

Amateur Repeater

Based on the F-D curves, a distance separation of 50 km is required to preclude Type A and B Profiler interactions with amateur repeaters if the systems operate co-channel.

EMC SUMMARY OF THE BAND 216-225 MHz

The results of the EMC analysis show that Wind Profilers are compatible with the systems in the environment in the 216-225 MHz band with regard to present and future use nationally. However, it will be difficult to accommodate either type of Wind Profiler due to the expected heavy concentration of land mobile and amateur repeaters in the 220-225 portion of the band on a primary basis. Type A Wind Profilers may be accommodated in the 216-220 MHz portion of the band with the following option. Within the 216-220 MHz, the frequency 219 MHz (2 MHz bandwidth) should be considered for Type A Wind Profiler operations in some geographic locations, subject to successful coordination with authorized users of the band and consideration of adjacent band TV-13 broadcast operations. A study would be required to determine the actual compatibility of Wind Profilers and TV receivers. Because of the characteristics assumed for the Type B profiler, it will not be possible to accommodate Type B in the frequency range 216-225 MHz. Internationally, since most of Region 1 and 3 is allocated to broadcasting, it is assumed not to be compatible with Wind Profiler operations. The national EMC suitability of this band is considered "conditional."

SUMMARY OF RESULTS FOR THE 216-225 MHz BAND

TABLE 6-5 below provides the co-channel distance separations required to preclude interference between Type A and B profilers and all the unclassified systems considered for this study in the band 216-225 MHz. F-D curves are given in Appendix B.

TABLE 6-5
CO-CHANNEL DISTANCE SEPARATIONS REQUIRED TO PRECLUDE INTERFERENCE BETWEEN WIND PROFILERS AND SYSTEMS OPERATING IN THE 216-225 MHz

	TYPE A PROFILER				TYPE B PROFILER			
	TO WP		FROM WP		TO WP		FROM WP	
ENVIRONMENTAL SYSTEMS[a]	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE
SPASUR[b]	170 km	120 km	30 km	20 km	80 km	80 km	20 km	10 km
TELEMETRY	5 km	5 km	10 km	10 km	5 km	5 km	5 km	5 km
LAND & MARITIME MOBILE	40 km	40 km	30 km	20 km	30 km	30 km	20 km	10 km
AN/GRC-103	10 km	10 km	30 km	20 km	10 km	10 km	20 km	10 km
AMATEUR REPEATER	50 km	50 km	50 km	30 km	40 km	40 km	30 km	20 km

[a] Wind Profiler sidelobe (85°-90° region) and environmental system mainbeam coupling unless otherwise noted.
[b] Wind Profiler sidelobe (85°-90° region) and SPASUR sidelobe coupling.

BAND II: 400.15-406 MHz

INTRODUCTION

Test measurements made at Goddard Space Flight Center in Greenbelt, MD (Reference 15) have indicated that Wind Profilers emissions may cause potential interference to certain satellite operations. In general, polar-orbiting satellites are more susceptible to the potential interference from Wind Profiler emissions than the geostationary satellites.

The potentially affected polar-orbiting satellites are NOAA 9 and 10, and three Soviet satellites. The operational geostationary satellites affected are GOES East and West. All the satellites carry sensitive receivers used to locate low-power emergency beacons from downed aircraft and ships in distress. The U.S. version for this system is named Search and Rescue Satellite-Aided Tracking (SARSAT) and operates on an adjacent frequency 406.0-406.1 MHz. A similar system is used by the Soviets called COSPAS and operates on the same frequency as SARSAT. Both the COSPAS and SARSAT operations are considered safety-of-life. Since Wind Profilers will transmit high power radar signals vertically, these signals will have the potential to interfere with the safety-of-life COSPAS/SARSAT operations. As a result, the EMC study for the 400.15-406 MHz band will first consider the interference potential to the COSPAS/SARSAT receiver aboard polar-orbiting satellites from Wind Profilers emissions at 404.37 MHz. The approach used to quantify the interference potential was to determine the interference-to-noise ratio at the IF portion of the COSPAS/SARSAT receiver from a single Wind Profiler as well as effects from multiple Wind Profilers in the deployment.

The characteristics for the two types of Wind Profilers assumed for this study are given in TABLE 3-2. These characteristics are representative of the two distinct types expected to be deployed, nationally. The characteristics assumed for the COSPAS/SARSAT receiver are given in TABLE 6-6.

TABLE 6-6
ASSUMED SYSTEM CHARACTERISTICS OF COSPAS/SARSAT

Frequency (MHz)	:	406.1
Height (km)	:	850
IF Selectivity	:	Figure 6-1
Bandwidth (3dB)	:	35 kHz
Gain (dBi)	:	-6
Noise Temperature (K)	:	1000
Antenna Polarization	:	Linear

All assumptions and references made to SARSAT equipped satellites (supplied by the U.S.) apply equally to the COSPAS equipped satellites.

As the COSPAS/SARSAT passes over the Wind Profiler deployment, it will receive power from all the Wind Profiler radars within its field of view. The amplitude of each signal will be determined by the gain of the satellite receiving antenna, the distance to the radar, and the gain of the radar transmitting antenna. The power received from any individual radar will fluctuate greatly due to the lode structure of the radar antenna, but the aggregate power from all the radars may be approximated by assuming that all radar antennas have the average gains that are given in TABLE 3-2.

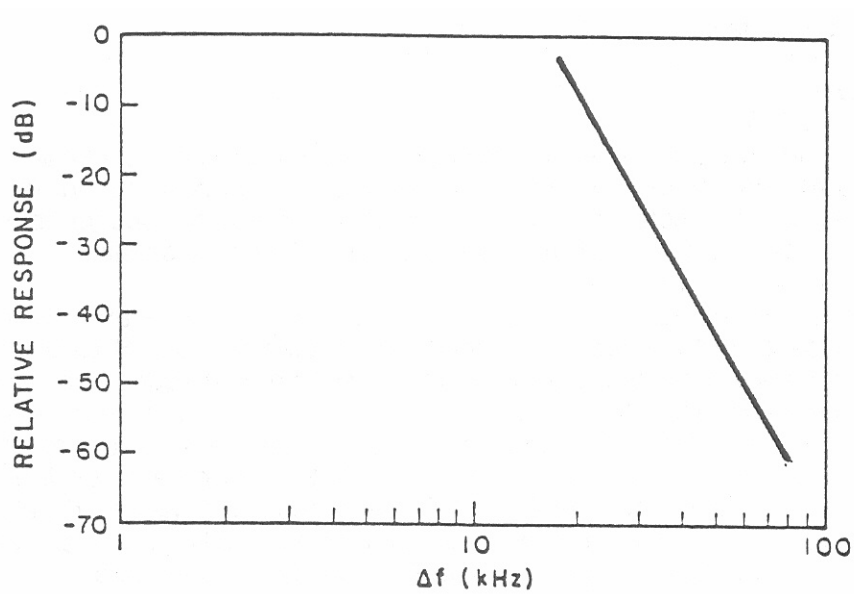

Figure 6-1. SARSAT 406 MHz receiver IF selectivity.

Single Case (mainbeam coupling)

Since the COSPAS/SARSAT receiver can be aboard polar orbiting satellites, it will eventually pass through the mainbeam of a single Wind Profiler. The maximum duration of a mainbeam exposure is approximately ten seconds. As the density of Wind Profilers increases, the potential number of mainbeam occurrences over any one orbit will increase. Under certain conditions mainbeam coupling from more than one Wind Profiler may occur if the profilers are separated by less than approximately 75 km. If this condition exists, the results stated in this section would have to be adjusted to take into account this occurrence. This can be approximated by the factor 10 log N, where N is the number of Wind Profilers having mainbeam coupling with the COSPAS/SARSAT. Equation (1) gives the various terms of the interference equation to determine the interference-to-noise ratio assuming the Wind Profiler is operating at 404.37 MHz and SARSAT operating at 406.1 MHz.

$$INR = P_t + G_t + G_r - L(d) - L_s - L_a - FDR[\Delta f] - N_s \qquad (1)$$

where:

P_t = The peak transmitting power of the Wind Profiler in dBm.
Type A - low mode 69 dBm, high mode 72 dBm
Type B - low and high mode 59 dBm

G_t = The Profiler gain towards the satellite (dBi) at nadir.
Type A = 32, Type B = 27

G_r = The Satellite antenna gain in dBi, -6 at nadir.

L(d) = The free space propagation loss in dB.

L(d) = 20 log d + 20 log F + 32.45
d is in kilometers and F is in MHz
= + 143.2

L_s = Waveguide and Insertion Loss, assumed 2 dB.

L_a = Loss due to cross polarization for mainbeam coupling.

FDR = Frequency-Dependent Rejection in dB.
= OTR + OFR, where OTR is the On-Tune rejection. OTR can be approximated by 20 log Bt/Br.
Type A - low mode 20 dB, high mode 11 dB
Type B - low mode 28 dB, high mode 19 dB
OFR can be approximated by from Figures 3-3 or 3-5 depending on Type A or B, high or low mode, respectively. For the case of Wind Profiler operating at 404.37 MHz and COSPAS/SARSAT operating at 406.1 MHz, the values are as follows:
Type A - low mode 40 dB, high mode 49 dB
Type B - low mode 20 dB, high mode 31 dB

N_s(dBm) = Satellite receiver noise level.
= -123.2 dBm

INR(dB) = Interference-to-Noise Ratio Assumed - 12. This value includes 25% of the aggregate permissible from all Wind Profilers to be accepted from all Wind Profilers combined.

and:

$$N_s = KTB_r \qquad (2)$$

where:

K	=	Boltsman constant 1.38 X 10^{-23} Joule per Kelvin.
T	=	Noise Temperature of the satellite receiver in Kelvin, 1000 K.
B_r	=	Satellite receiver bandwidth in Hz

Substituting the Wind Profiler characteristics for the Type A (low mode) and the COSPAS/SARSAT characteristics contained in TABLE 6-6 into equation 1 yields:

$$INR = 69 + 32 - 6 - 143.2 - 2 - 0 -[20 + 40] + 123.2$$
$$= 13$$

Additional INR values for Type A (low mode), Type B (high and low mode) can be obtained in a similar matter by substituting the values into Equation 1. These values are summarized in TABLE 6-7.

TABLE 6-7
INR VALUES FOR TYPE A and B WIND PROFILERS
(MAINBEAM COUPLING)

	TYPE A	TYPE B
Low mode	13	10
High mode	16	8

The computed INR values contained in TABLE 6-7 for the Wind Profiler mainbeam coupling condition indicates that the required INR (-12 dB) is exceeded by 20 dB to 28 dB, depending on type of profiler and mode selected.

In addition to computing the INR for Wind Profiler mainbeam coupling, the frequency separation values to prevent interference into the COSPAS/SARSAT receiver for Wind Profiler emissions can also be determined for a given INR threshold. This required frequency separation to preclude interference can be determined by rearranging the terms given in Equation (1) into the following equation and solving for the OFR value.

$$OFR = P_t + G_t + G_r - L(d) - L_s - L_a - OTR - N_s - INR(-12) \quad (3)$$

The required OFR values for each type of Wind Profiler can be obtained by substituting the appropriate characteristics into the equation (3). From these OFR values, the appropriate distance separations can be determined for each type of Wind Profiler (Low and High Mode) from Figures 3-3 or 3-5, respectively. TABLE 6-8 summarizes the OFR values and required frequency separations to preclude interference from each type of Wind Profiler (low and high mode) to the COSPAS/SARSAT receiver. The values contained in TABLE 6-8 indicate that for the single Wind Profiler mainbeam coupling condition, the frequency separation required varies from 4.1 MHz to 4.7 MHz depending on the type of profiler and mode selected.

TABLE 6-8 CALCULATED OFR VALUES AND REQUIRED FREQUENCY SEPARATIONS FOR TYPE A AND B PROFILERS (Mainbeam Coupling)				
	Type A		Type B	
	OFR(dB)	ΔF(MHz)	OFR(dB)	ΔF(MHz)
Low Mode	65	4.5	42	4.4
High Mode	77	4.7	51	4.1

Multiple Case

In addition to considering the emissions from the mainbeam of a single Wind Profiler, the power received at the COSPAS/SARSAT receiver must also consider sidelobe emissions of other Wind Profilers in the deployment. The number of Wind Profiler radars seen by the satellite will depend on the number in the deployment.

Stated in a previous section was a discussion on the deployment philosophy for each of the two types of Wind Profilers assumed for this study. For Type A profilers, the "NOAA Type," the initial deployment will consist of 30 (Figure 3-1) with expected numbers to reach approximately 200-300 to form a grid across the U.S. The number of radars as seen by the COSPAS/SARSAT satellite will vary depending on the central Earth's angle, measured at the Earth's center between the satellite and the radar. A draft report (Reference 11) delineates one method of determining the number of "NOAA type" radars as a function of Central earth angle. For this study it is assumed one-half of the number of radars given in Reference 11 will be deployed as a function of Central earth angle. TABLE 6-9 summarizes the Type A Wind Profiler's Angle Range, the Antenna gain, Central earth angle, and number of Radars of "NOAA Type" radars as a function of Central Earth angle. No radars are considered beyond 15 degrees central Earth angle because that is approximately the extent of the region (continental US and southern Canada). For Type B profilers, the expected deployment of this type of profiler is unknown. As a result, the numbers of Type B profilers to be seen by COSPAS/SARSAT satellite as a function of Central Earth angle are assumed to be the same as those given for Type A. TABLE 6-10 summarizes the Type B Wind Profiler's Angle Range, the Antenna gain, Central earth angle, and number of radars as a function of Central Earth angle.

TABLE 6-9 NUMBER OF TYPE A PROFILERS TO BE DEPLOYED AS A FUNCTION OF CENTRAL ANGLE (excluding mainbeam)			
Angle Range (deg.)	Gain (dBi)	Central Earth Angle (deg.)	Number of Radars
2.5-15	10.7	0.3-1.8	2.7
15-30	0	1.8-3.8	9.6
30-60	-10	3.8-10.1	74.7
60-90	-20	10.1-15.0	104

TABLE 6-10 NUMBER OF TYPE B PROFILERS TO BE DEPLOYED AS A FUNCTION OF CENTRAL ANGLE (excluding mainbeam)			
Angle Range (deg.)	Gain (dBi)	Central Earth Angle (deg.)	Number of Radars
4-15	5	.47-1.8	2.7
15-30	2	1.8-3.8	9.6
30-60	-4	3.8-10.1	74.7
60-90	-13	10.1-15.0	104

The approach used for the multiple case was to quantify the interference potential by determining interference-to-noise ratio at the satellite receiver from sidelobe emissions of Wind Profilers. This approach was similar as described for the mainbeam case. However, it is noted that the results obtained for the multiple emitter case represent an upper bound since the effects of pulse overlap due to multiple emitters was not included. The inclusion of considering pulse overlap would result in lower values than computed for the upper bound. Using Equation (1), the variable terms in the equation depend on the location of the radars with respect to the satellite. The COSPAS/SARSAT receiver antenna gain variation with nadir angle compensates for the increase in path loss due to the increasing distance, so that the variation in the power received from the radar is completely (within 1 dB) determined by the radar antenna gain. This allows equation (1) in determining the INR to be simplified for each step of the central Earth angle by multiplying the number of radars assumed for that angle:

$$INR = P_t + G_t + 10 \log N + G_r + - L(d) - L_s - L_a - FDR [\Delta f] - N_s \quad (4)$$

where:

N = number of Wind Profilers being considered as a function of Central Earth Angle.

Using Equation (4), the INR values can be computed for each of the Central Angles given in TABLES 6-4 and 6-5. For example, the INR for the Central Angle .3 - 1.8 for the Type A profiler (low mode) can be computed by substituting the Wind Profiler characteristics for Type

A (low mode) contained in TABLE 3-2, the COSPAS/SARSAT characteristics contained in TABLE 6-1, and the number of Wind Profiler radars given for the Central Angle .3-1.8 (2.7) contained in TABLE 6-9. The equation yields:

$$INR = 69 + 10.7 + 4.3 - 6 - 143.2 - 2 - 0 - [20 + 40] + 123.2$$
$$= -4$$

Additional INR values as a function of Central Earth Angle for Type A (low mode) and Type B (high and low mode) profilers can be obtained in a similar manner by substituting the appropriate values into Equation 4. These values are summarized in TABLES 6-11 and 6-12, respectively.

TABLE 6-11
INR VALUES FOR TYPE A PROFILERS
(SIDELOBE COUPLING)

Central Earth Angle (deg.)		INR Values	
		Low Mode	High Mode
.3 - 1.8		-4	-1
1.8 - 3.8		-9.2	-6.2
3.8 - 10.1		-10.3	-7.3
10.1 - 15		-18.9	-15.9
	OVERALL	-2.0	0.95

TABLE 6-12
INR VALUES FOR TYPE B PROFILERS
(SIDELOBE COUPLING)

Central Earth Angle (deg.)		INR Values	
		Low Mode	High Mode
.47 - 1.8		-7.7	-9.7
1.8 - 3.8		-5.2	-7.2
3.8 - 10.1		-2.3	-4.3
10.1 - 15		-9.9	-11.9
	OVERALL	0.65	-1.3

The computed overall INR values contained in TABLES 6-11 and 6-12 for the sidelobe Wind Profiler coupling condition indicate the required INR (-12 dB) will be exceeded between 10 and 13 dB, depending on the type of profiler selected and mode of operation.

In addition to computing the overall INR due to the sidelobe emissions of Wind Profilers contained in the deployment, the required frequency separation to prevent interference into the COSPAS/SARSAT receiver can also be determined in a similar method as was done for the mainbeam Wind Profiler emissions. This required frequency separation to preclude interference can be determined by rearranging the terms given in Equation (4) into the following equation and solving for the OFR value.

$$OFR = P_t + G_t + 10 \text{ Log } N + G_r - L(d) - L_s - L_a - OTR(\Delta F) - N_s - INR(-12) \quad (5)$$

where:

N = number of Wind Profilers being considered as a function of Central Earth Angle.

The required OFR values for each type of Wind Profiler can be obtained by substituting the appropriate characteristics into the equation (5). From these OFR values, the appropriate frequency separations can be determined for each type of Wind Profiler (low and high Mode) from Figures 3-3 and 3-5, respectively. TABLES 6-13 and 6-14 summarize the OFR values and required frequency separations to preclude interference from each type of Wind Profiler (low and high mode) to the COSPAS/SARSAT receiver as a function of Central Earth Angle. From TABLES 6-13 and 6-14, the overall required frequency separations to preclude interference to the COSPAS/SARSAT for the sidelobe coupling condition varied from 1.3 MHz (54.5% of Wind Profiler radars 104/191) to 3.0 MHz (39.1% of Wind Profiler radars 74.7/191), depending on the type of profiler and mode being considered.

TABLE 6-13
CALCULATED OFR VALUES AND REQUIRED FREQUENCY SEPARATIONS FOR TYPE A PROFILERS
(Sidelobe Coupling)

Central Earth Angle (deg.)	Low Mode OFR (dB)	Low Mode ΔF(MHz)	High Mode OFR (dB)	High Mode ΔF(MHz)
.3 - 1.8	48	2.7	60	2.9
1.8 - 3.8	42.8	2.0	54.8	2.2
3.8 - 10.1	41.7	1.9	53.2	2.1
10.1 - 15	33.1	1.3	45.1	1.5

TABLE 6-14
CALCULATED OFR VALUES AND REQUIRED FREQUENCY SEPARATIONS FOR TYPE B PROFILERS
(Sidelobe Coupling)

Central Earth Angle (deg.)	Low Mode OFR (dB)	Low Mode ΔF(MHz)	High Mode OFR (dB)	High Mode ΔF(MHz)
.47 - 1.8	24.3	2.2	33.3	2
1.8 - 3.8	26.8	2.6	35.8	2.2
3.8 - 10.1	29.7	3.0	38.7	2.6
10.1 - 15	22.1	2.0	31.1	1.9

Combination of Mainbeam and Sidelobe Wind Profiler Emissions

When the COSPAS/SARSAT receives signals from both the mainbeam and sidelobe of the various profilers in the deployment, the signals received from the mainbeam of any particular Profiler will dominate. As a result, when this condition exists, the INR and required frequency separation values stated for the mainbeam condition can be used.

Combination of Various Types of Profilers

The previous section calculated INR and required frequency separation values for both single and multiple Wind Profiler emissions from each of the two types of Wind Profilers (including high and low mode) assumed for the study. Since an actual deployment will consist of both types of Profilers assumed for this study as well as other types of Profilers with characteristics differing from those given in this study, the computed INR and required frequency separation values would have to be adjusted to take into account the combination of the various types of profilers to be deployed.

EMC SUMMARY OF THE 400.15-406 MHz BAND

Based on the assumptions and methods used for this study to determine EMC with the safety-of-life COSPAS/SARSAT system at 406-406.1 MHz, it was determined that Wind Profilers operating in the 400.15-406 MHz band would not be compatible. Moreover, it is noted that Wind Profilers having characteristics similar to those assumed for Type B are less compatible with COSPAS/SARSAT operations than those given for Type A.

A possible method to operate compatibly with the COSPAS/SARSAT would require the Wind Profiler to shut down as the COSPAS/SARSAT passes overhead. Although this shut down method may be controlled as well as enforceable on a national basis, it is uncertain if similar procedures would be followed by other administrations. As a result, the COSPAS/SARSAT safety-of-life service may be at risk.

At this time, due to the incompatibility with COSPAS/SARSAT operations, the 400.15-406 MHz band is determined to be unsuitable for Wind Profiler operations both nationally and internationally. As a result, no other systems operating in the 400.15-406 MHz band were investigated for compatibility with Wind Profiler operations.

It is recognized that more detailed studies may show improved compatibility with COSPAS/SARSAT. In addition, future design changes to existing 404.37 MHz Wind Profilers may increase compatibility with COSPAS/SARSAT. Any changes to existing 404.37 MHz Wind Profilers to eliminate the potential interference to COSPAS/SARSAT must also take into consideration other factors such as:

1. Performance Objectives
2. Number of Wind Profilers
3. Deployment of Profilers
4. Effects of Single versus Aggregate (both mainbeam and sidelobes)
5. Effects on other Satellites [e.g., SARSAT receiver on GOES (geostationary), ARGOS (401.65 MHz) and Data Collection platforms (DCP's)]
6. Effects on profiler operations from other systems
7. Time to implement
8. Potential equipment malfunction or human error
9. Development, adoption and enforcement of spectrum standards.

However, due to the potential national and international regulatory burdens associated with, 1) establishing and ensuring the Wind Profiler design which would ensure the compatibility with the COSPAS/SARSAT and other systems, and 2) the potential liability associated with a safety-of-life service, the 400.15-406 MHz band would remain unsuitable for Wind Profiler operations.

BAND III: 420 - 450 MHz

TABLES 6-15 and 6-16 below show the services considered for EMC analysis and the characteristics assumed for each service or system considered.

TABLE 6-15
SERVICES CONSIDERED FOR EMC WITH WIND PROFILERS

SERVICES	GOVERNMENT	NON-GOVERNMENT
RADIOLOCATION	Yes	N.A.
Radiolocation (Pulse-ranging)	No	No
Low Power Remote Control	Yes	N.A.
LAND MOBILE	N.A.	Yes
Amateur	N.A.	Yes (Repeaters and TV only)

GOVERNMENT SYSTEMS

This band is used by the DoD primarily for radiolocation and low power remote control of drones. To determine the compatibility with radiolocation systems, representative systems were identified for each type of installation: ground-based, shipborne, and airborne platforms. The F-D curves are provided in Appendix B.

To determine compatibility with drone control operations, a typical drone system was used to represent all drone control operations since their parameters are similar. The F-D curves are provided in Appendix B.

Pulse-ranging radars were not considered because of the limited areas of operation and secondary status.

Major Radiolocation (Radar) Systems

<u>Land based Radars</u>

Land based radar sidelobe to profiler sidelobe coupling requires co-channel distance separations of 100 km. Although moderate frequency and distance separations are necessary to preclude potential interactions between the Wind Profilers and these radar systems, other

TABLE 6-16
ASSUMED CHARACTERISTICS FOR SYSTEMS IN THE 420-450 MHz BAND

	LAND BASED RADAR	AIRBORNE RADAR	SHIPBORNE RADAR	DRONE
Power	98 dBm	93 dBm	86 dBm	50 dBm
Emission Designator	2M00P0N	7M00P0N	3M00P0N	900K00F2D
Antenna Gain	0 dBi (SL/BL)	22 dBi (MB) 0 dBi (BL/SL)	0 dB (median)	5 dBi (MB) (Ground) 0 dB (SL) (Drone)
Emission Curve	-3 dB 1 MHz -20 dB 2 MHz -70 dB 34 MHz	-3 dB 5 MHz -20 dB 7 MHz -70 dB 30 MHz	-3 dB 2 MHz -20 dB 3 MHz -70 dB 20 MHz	-3 dB 0.6 MHz -20 dB 0.9 MHz -60 dB 1.8 MHz -70 dB 2.0 MHz
IF Selectivity Curve	-3 dB 7 MHz -60 dB 20 MHz	-3 dB 3 MHz -83 dB 20 MHz	-3 dB 2 MHz -103 dB 20 MHz	-3 dB 0.6 MHz -20 dB 0.9 MHz -60 dB 1.8 MHz -70 dB 2.0 MHz
Noise Level	-109 dBm	-104 dBm	-106 dBm	-120 dBm
Antenna Type	Phased Array	Broadside Array	Parabolic Reflector	Corner reflector Dipole Array
Antenna Height	30 meters	20,000/40,000 ft.	9 meters	3 meters (ground) 20,000 ft.

TABLE 6-16 (Continued)
ASSUMED CHARACTERISTICS FOR SYSTEMS IN THE 420-450 MHz BAND

	AMATEUR TV	AMATEUR REPEATER	LAND MOBILE
Power	47 dBm	50 dBm	53 dBm
Emission Designator	6M0C3FNN	16K0F3E	16K0F3E
Antenna Gain	10 dBi	9 dBi	3 dBi
Emission Curve	-3 dB 4.2 MHz -20 dB 4.75 MHz -60 dB 6.0 MHz	-3 dB 16 kHz -20 dB 20 kHz -40 dB 26 kHz -60 dB 30 kHz	-3 dB 3 kHz -20 dB 16 kHz -40 dB 18 kHz -60 dB 25 kHz
IF Selectivity Curve	-3 dB 5 MHz -43 dB 50 MHz	-3 dB 16 kHz -20 dB 20 kHz -40 dB 26 kHz -60 dB 30 kHz	-3 dB 16 kHz -20 dB 25 kHz -40 dB 28 kHz -60 dB 32 kHz
Noise Level	-100 dBm	-120 dBm	-120 dBm
Antenna Type	Vertical collinear (some horizontal)	Vertical collinear	Vertical collinear
Antenna Height	60 meters	60 meters	30 meters

factors may aid in precluding interference, such as signal processing that is incorporated in both the Wind Profilers and the radars, and anti-jam circuitry incorporated by most radars. In addition, the actual F-D curves may be smaller when terrain factors are considered. Since many of the radars frequency hop through the band, frequency separation may not preclude interference. Therefore, adequate distance separations between Wind Profilers and land based radars may be the best way to preclude potential interference between these systems.

Shipborne Radar

For shipborne radars which may scan 360 degrees in the horizontal plane, a median gain to profiler sidelobe gain coupling requires a co-channel distance separation of 50 km. Its typical operations are offshore, at sea and at naval sea ports for test and maintenance. Frequency and/or distance coordination should preclude interactions with shipborne radars. During testing and maintenance of the shipborne radars in port or offshore, interference would be short-term and intermittent.

Airborne Radar

Based on the assumptions, characteristics, and methods to determine compatibility, airborne radars pose the greatest potential interference problem compared to land based and shipborne. Airborne radars require greater F-D separations compared to surface radars. Based on the study to preclude interference, the necessary co-channel distance separations for Type A profilers varied from 250 km to 630 km depending on altitude of airborne radar, mode of operation, and antenna coupling. Signal processing and anti-jam circuitry may aid in precluding potential interference. Since many of the radars frequency hop through the band, frequency coordination could be used to preclude potential interactions when an airborne radar is in vicinity of a Wind Profiler if the airborne radar can notch-out channels.

Drone Control

Interactions with drone control operations should be manageable through frequency coordination, since their operations are limited to military installations which are primarily coastal. A distance separation of 10 km is required to preclude co-channel interference to the Wind Profilers by the ground telecommand transmitter. A distance separation on the order of 320 km is required to preclude interference to an airborne drone at an altitude of 20,000 ft. from the Wind Profiler when there is co-channel coupling.

Drone systems are capable of operating on any selected frequency in the band for normal drone control. The frequency 425 MHz is often used for flight termination in case of a malfunction of the drone. The frequency 425 MHz should be avoided by Wind Profilers since it is considered a safety-of-life function.

NON-GOVERNMENT

This band is allocated to the amateur service for various operations throughout the U.S. except as stated in footnote NG135 -- North of line A as defined by Section 2.1 [also defined in Arrangement D of the Canada-United States Coordination Agreement (Chapter 3 of the NTIA Manual)] in the frequency range 420-430 MHz. The frequency range 420-430 MHz is allocated to the land mobile service within a 50 mile radius of Detroit, MI; Cleveland, OH; and Buffalo, NY. The land mobile systems have parameters similar to those in the 216-220 MHz band. The amateurs have various operations in this band that are on a secondary basis (see Section 5).

Pulsed-ranging radars were not considered because of the limited areas of operation and secondary status.

Amateur

The frequency range 430-440 MHz is used by the amateurs on a secondary basis for weak signal operations, such as EME, and amateur satellite systems. These systems were not studied but may be affected. The frequency ranges 420-426, 426-432, and 438-442 MHz are used by the amateurs on a secondary basis for amateur TV (ATV) operations. Co-channel distance separations of 40 km are necessary to preclude interference between profilers and ATV. The amateur repeaters operate on a secondary status in the band 442-450 MHz and have parameters similar to those in the 222-225 MHz band. Co-channel distance separation of 50 km is necessary to preclude interactions between the Wind Profiler and the amateur repeaters.

Land Mobile

For co-channel operation with land mobile, distance separations of 40 km are necessary. Due to the mobile nature of the land mobile service, potential interference may be intermittent; however, heavy land mobile usage may make frequency assignments of Wind Profilers in the vicinity of these cities prohibitive and should be coordinated to avoid interference to police, fire and rescue operations.

EMC SUMMARY OF THE BAND 420-450 MHz

Based on the assumptions, characteristics, and methods to determine compatibility, it was determined that there is no frequency(s) available in the 420-450 MHz band to be interference free for the mutual operation of Wind Profiler and other systems that operate nationally in the band. Specifically, the level of interference between Wind Profilers and other systems as well as the F-D separations necessary to avoid potential interference will vary depending on the specific system (i.e., radars, amateurs) being considered. Although it was determined there is no one particular frequency(s) that Wind Profilers could operate interference free, a discussion on the various factors associated with determining a candidate frequency to minimize interference between Wind Profilers and other systems in the 420-450 MHz band is given.

In general, the band is used nationally by (1) the military for radiolocation systems, (2) the military for drone operations at military bases and test ranges, and (3) amateurs. The military operations have primary status and amateur operations have secondary status. In addition, this band is the only 30 MHz of spectrum available for military radiolocation below 1 GHz nationally. Due to the altitudes of airborne platforms (i.e., airborne radars and drones), they pose the greatest interference potential for interactions (i.e., largest F-D separations) with Wind Profilers. The majority of the military radars have the capability to operate throughout a portion or over the entire band. Although there are only a few high powered fixed land based radars widely dispersed throughout the country, fixed radar operations are not limited in location and may operate anywhere in the future. In addition, the frequency 425 MHz is primarily used by the military for flight termination of drones; therefore, it should be avoided since this function is considered safety-of-life. In the future there may be more drone control operations including flight termination throughout other parts of the 420-450 MHz band.

The 420-430 MHz portion of the 420-450 MHz band currently contains the highest number of GMF assignments of the three sub-bands. The military has many assignments for radiolocation and drone control operations, including flight termination (425 MHz). Land mobile operates within a 80.5 km (50 miles) radius of Detroit, MI; Cleveland, OH; and Buffalo, NY. The band is used on a secondary basis for amateur TV operations in various areas of the country. Specifically, two ATV channels (420-426 and 426-432 MHz) are designated by the amateurs. Since the 420-430 MHz sub-band is the most congested and has flight termination for drones, it is not considered the most suitable candidate sub-band for Wind Profiler operations.

The 430-440 MHz portion of the band currently has the second highest number of GMF assignments. This band is the only 10 MHz of spectrum allocated for military radiolocation below 1 GHz outside the U.S. Furthermore, if the military had to blank out channels to minimize interference, the 430-440 MHz seems to be the least likely candidate band since it is the middle portion of the 420-450 MHz. The 430-440 MHz sub-band also contains sensitive amateur receiver and satellite operations. 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 band edge would be potentially more acceptable than a frequency closer to the center or lower end. As a result, the candidate frequency 449 MHz 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. Furthermore, to ensure compatibility with military airborne platforms, Wind Profilers would be required to operate on a secondary basis. 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) to 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 potential impact to military operations. Although two candidate frequencies have been identified for Wind Profiler operations, only one frequency should be ultimately selected to aid in spectrum conservation. If possible, once the frequency has been determined nationally for Wind Profiler operations, the same frequency should be pursued internationally.

Nationally, EMC suitability of the band 420-450 MHz is conditional.

SUMMARY OF RESULTS FOR THE 420-450 MHz BAND

TABLE 6-17 provides a summary of the co-channel distance separations required to preclude interference between Type A and B profilers and all the unclassified systems considered for this study in the band 420-450 MHz. F-D curves are given in Appendix B.

TABLE 6-17
CO-CHANNEL DISTANCE SEPARATIONS REQUIRED TO PRECLUDE INTERFERENCE BETWEEN WIND PROFILERS AND SYSTEMS OPERATING IN THE 420-450 MHz BAND

	TYPE A PROFILER				TYPE B PROFILER			
	TO WP		FROM WP		TO WP		FROM WP	
ENVIRONMENTAL SYSTEMS[a]	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE	HI-ALT MODE	LO-ALT MODE
LAND MOBILE	40 km	30 km	30 km	20 km	30 km	30 km	10 km	10 km
AMATEUR REPEATER	50 km	40 km	40 km	30 km	40 km	40 km	30 km	20 km
AMATEUR TV	30 km	30 km	40 km	40 km	30 km	30 km	40 km	40 km
LAND BASED RADAR[b]	60 km	70 km	40 km	30 km	100 km	100 km	30 km	30 km
AIRBORNE RADAR[c]								
Gain = 22 dBi								
Alt. 20,000 ft.	360 km	370 km	350 km	340 km	520 km	520 km	320 km	320 km
Alt. 40,000 ft.	490 km	490 km	460 km	450 km	630 km	630 km	440 km	440 km
Gain = 0 dBi								
Alt. 20,000 ft.	290 km	310 km	270 km	260 km	360 km	360 km	250 km	250 km
Alt. 40,000 ft.	400 km	420 km	380 km	370 km	480 km	480 km	360 km	360 km
SHIPBORNE RADAR[d]	30 km	40 km	20 km	20 km	50 km	50 km	20 km	20 km
DRONES[e]	10 km	10 km	320 km	300 km	10 km	10 km	290 km	270 km

[a] Wind Profiler sidelobe (85°-90° region) and environmental system mainbeam coupling unless otherwise noted.
[b] Wind Profiler sidelobe (85°-90° region) and land based radar sidelobe coupling.
[c] Wind Profiler sidelobe (60°-90° region) and airborne radar mainbeam (22 dBi) and sidelobe (0 dBi) coupling.
[d] Wind Profiler sidelobe (85°-90° region) and shipborne median coupling.
[e] Wind Profiler sidelobe (60°-90° region) and drone (airborne) sidelobe coupling.