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RN06-20

ARRL 500-kHz experimental license WD2XSH

by

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Abstract

Under the experimental license WD2XSH, a group of radio amateurs have begun exploration of new uses for the historic 600-meter (500-kHz) band. For nearly a hundred years, this band was the internationally designated distress frequency for maritime telegraphy. However, it now used only by “museum” stations. This band has the potential to give the amateur service a unique capability for ultra-reliable regional ground-wave communication. Such communications are based upon ground-wave propagation and therefore not subject to interruption by solar storms or other events that disrupt the ionosphere. This frequency range also offers unique opportunities for experimentation with antennas, propagation, modulation, and signal processing. The 21 WD2XSH stations are operating from 505 to 510 kHz with up to 20 W ERP. The tests conducted during this experiment will establish that we cause no harmful interference and determine the communication capabilities of this band.

Indexing Terms

Radio, amateur
Communication, MF

1. INTRODUCTION

The first International Wireless Telegraph Convention, held in Berlin on November 3, 1906, designated 500 kHz as the maritime international distress frequency. This same convention also designated "SOS" to replace "CQD" as the distress signal.

The "600-meter band" (495 - 510 kHz) for nearly 100 years served as the primary calling and distress frequency for maritime communication. In the 1980s, a transition began to the Global Maritime Distress Signaling System (GMDSS), which uses UHF communication via satellite. In the 1990s, most countries ceased using and monitoring CW communications. Today, the 600-meter band is idle with the exception of occasional transmissions by historical maritime stations.

The frequencies below 1.8 MHz have been little explored by radio amateurs since our banishment to "200 meters and down" in 1912. The 600-meter band is located (Figure 1) near the geometric mean of the 2200-m (137 kHz) and 160-m (1.8 MHz) amateur bands. It is of interest to radio amateurs for a number of reasons:

- Ultra-reliable emergency communications via ground wave,
- Different propagation and noise environment, and
- Experimental work with antennas, modulation, and signal processing.

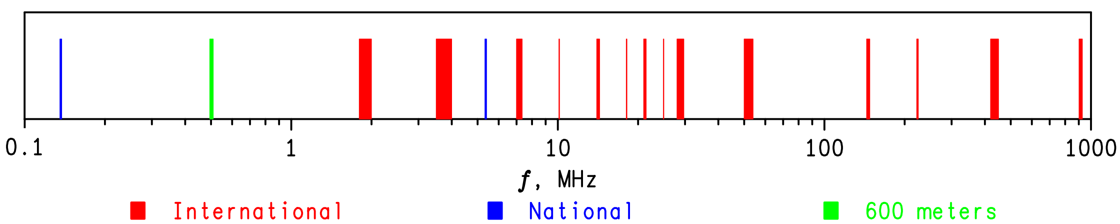

Figure 1. Amateur bands.

The WD2XSH experimental license allows a group of 21 amateurs to begin exploration of this unique part of the spectrum, hopefully paving the way for a future amateur band. The two key objectives of the license are:

- Demonstration of noninterference with other services, and
- Experimentation with regional ground-wave communication.

Naturally, the participants also want to determine what kind of DX can be achieved using both in normal CW and QRSS.

2. GROUND-WAVE COMMUNICATION

Amateur radio has proved its value to society by providing communication in the aftermath of Hurricane Katrina and other natural disasters. As Katrina demonstrated, natural disasters can destroy or render inoperative most or all of the normal communication infrastructure (land-line telephone, cell phone, land mobile). Amateur radio is a “distributed system” that does not depend upon fixed infrastructure, hence it is well suited to providing post-disaster communications. Luckily, following Katrina the sun was not having an “event,” the ionosphere was behaving, and HF communications worked well.

Ground-wave (also called "surface-wave") propagation at low and medium frequencies can provide reliable communication over significant ranges. The ground-wave signal propagates along the surface of the earth. Such communication is omni-directional and continuous and is therefore well-suited for "party-line" communication among all terminals in a network. Since the ground-wave signal is not dependent upon the ionosphere, communications based upon ground waves are not interruptable by solar events (sunspots, solar storms, coronal mass ejection) or a high-altitude nuclear detonation that disturb the ionosphere. A recent burst of solar activity (November 2003) produced significant aurora and disrupted HF ionospheric communication for several days.

The optimum frequency for ground-wave communication depends upon antenna efficiency, ground-wave propagation loss, and atmospheric noise. Vertical antennas with heights of 40 to 50 ft are readily constructed from aluminum tubing. For communication with such an antenna over average ground to distances of 100 - 300 km (60 - 200 mi), the best signal-to-noise ratio (SNR) per watt of transmitter output (see Appendix A) occurs in the range of 400 to 600 kHz, as shown in Figure 2. The 600-m amateur band is therefore ideal for amateur ground-wave emergency communications.

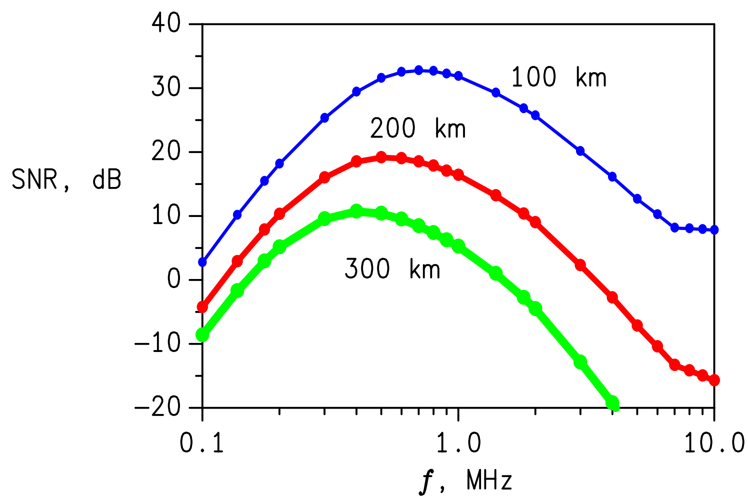

Figure 2. Ground-wave SNR as a function of frequency for typical amateur use.

An "Amateur Ground-Wave Emergency Net" operating in the 600-m band will provide uninterruptable emergency/disaster/homeland-security communication across a midwestern-sized state (e.g., Iowa). Fixed nodes will be established in major cities (e.g., Waterloo, Des Moines, Souix City) and will interface with local VHF/UHF amateur networks. Transportable units can be deployed to the site of an emergency (e.g., a tornado). Such units can be transported by pick-up truck or van and will consist of 100-500-W transmitters, laptop computer, and a 40 to 50-ft vertical antenna that is assembled from aluminum tubing.

No current amateur frequency allocations provide this kind of coverage. The 160, 80, 60, and 40-meter bands provide regional coverage through near-vertical-incidence sky-wave (NVIS).

However, different frequencies are required to communicate over different distances and communication is subject to ionospheric disturbances. Troposcatter at VHF and UHF can also provide coverage over distances. However, directional antennas are required, hence coverage is point-to-point rather than regional. The proposed 137-kHz band is not suitable as it has a very limited frequency allocation and the efficiency of realistic amateur antennas is very low for 137 kHz.

3. EXPERIMENTS

A band at 600 meters will offer radio amateurs unique opportunities for experimentation in several areas:

- Electrically short antennas,
- Propagation and noise,
- Modulation and signal processing.

At first thought, it may seem that all of these issues have been fully explored and documented. Indeed, many aspects are explained in text books and engineering literature. However, there has been little to no application of modern technology to this frequency range, and few text books treat the real-life issues that confront radio amateurs operating from limited real estate with limited power and limited resources. The brief discussion below highlights some areas for exploration by amateurs.

Electrically Short Antennas

Virtually all amateurs will be using electrically short - and often very short - antennas. The issue for a radio amateur is not simply how to maximize radiation resistance or gain. It is how to maximize the radiated signal from an antenna constructed in a limited space, built on a limited budget, and unavoidably placed near trees and other objects. Having the capability to set-up nodes for emergency communications adds portability and easy deployment to the list of design issues.

Short, top-loaded monopoles are generally used with nondirectional beacons (NDBs) that operate at low and medium frequencies. These antennas work well in the clear areas at the NDB sites, but as some low-frequency experimenters ("lowfers") have recently discovered, nearby trees appear to cause significant losses, especially when wet. The most likely explanation is that the electric-field intensity increases as the frequency decreases and the antenna becomes shorter electrically. The electric-field applied to the trees causes the losses, which are negligible at HF but significant at MF and LF. However, this problem has not been well explored.

In contrast, loop antennas create intense magnetic near fields. This allows them to be placed in forrested areas without significant loss from the trees. However, magnetic fields flowing in the conducting ground cause losses much as do the fields surrounding a monopole antenna. Little exploration has been done on these losses or ground-radial systems for minimizing the loss.

The limited real estate available to the average amateur precludes the installation of ideal grounding systems. In poor soil, the common ground to the power grid and water system are likely to be more effective than ground rods and radial systems of limited size. This has implications for both modelling antennas and for determining what grounding system to use. Grounding systems are yet another area for experimentation.

Propagation and Noise

Virtually all long-range HF operation by amateurs relies on sky-wave (ionospheric) propagation. At 500 kHz, however, both sky-wave and ground-wave propagation can be utilized. The effects of the D layer are much more pronounced at 500 kHz than at higher frequencies, resulting in almost a complete absence of useable sky wave during the daylight. Atmospheric noise is more impulsive, and the level of man-made noise is higher.

Modulation and Signal Processing

The limited bandwidth available at 500 kHz makes narrowband digital modes of great interest. BPSK and QPSK provide the lowest bit-error rate for a given amount of signal power. PSK-31 is therefore a natural candidate for this application.

However, improvements may be possible. PSK-31 uses sine-wave shaping of its data pulses to provide synchronization as well as to keep the signal in a very narrow bandwidth. This amplitude modulation necessitates a linear RF-power amplifier and results in an average transmitted power that is only half of the peak power capability of the amplifier.

Minimum-shift keying (MSK) is a form of QPSK that (like PSK-31) employs sinusoidally shaped data pulses to constrain bandwidth. Delaying the modulation on the quadrature carrier by half a bit results in a constant-amplitude composite signal. The average power is the same as the peak power, and the signal can be amplified by a nonlinear power amplifier. Establishing synchronization is, however, more difficult. The Spectran software contains an MSK-31 mode that otherwise follows PSK-31 protocols. However, MSK has been little used in amateur applications, so evaluation of its capabilities is certainly an area for investigation. Development of a synchronization scheme suited to short amateur-type transmissions will probably be needed. This might be embodied in software tailored to this frequency range, much as the K1JT software is tailored to meteor-burst and EME communications.

At 500 kHz, signals may travel significant distances by both ground- and sky-wave propagation. In some cases, the resultant "multipath" signal reception may make it difficult or impossible to receive phase-modulated signals such as PSK-31. Ground-wave/sky-wave interference was in fact common in CW signals used in the Decca LF navigation system, and this phenomenon has been observed in reception of PSK-31 signals from experimental 137-kHz station WC2XSR/13 after sunset. If this proves to be the case for 500 kHz, it may be necessary to develop more sophisticated signal processing or to revert to something like FSK-31 that does not use phase information.

The more impulsive character of the atmospheric noise at 500 kHz means that there is more opportunity to reduce its effective level through nonlinear signal processing such as clipping and blanking. The presence of higher levels of man-made noise makes techniques such as noise cancellation of great interest.

4. WD2XSH LICENSE

WD2XSH is an experimental license issued to the ARRL under part 5 of the FCC rules. The locations of the 21 stations currently authorized to operate are shown in Figure 3. (Two other stations originally included in the FCC grant dropped-out). The basic parameters of the license are:

- Period: 09/13/2006 - 09/01/2008,
- Radiated power: 20 W ERP,
- Frequencies: 505 - 510 kHz, and
- Modulation: CW (including QRSS).

The experiment coordinator (the author) has for the time being restricted the midwest stations to 505 - 508 kHz to ensure there is no interference with NDB “OF” in Nebraska.

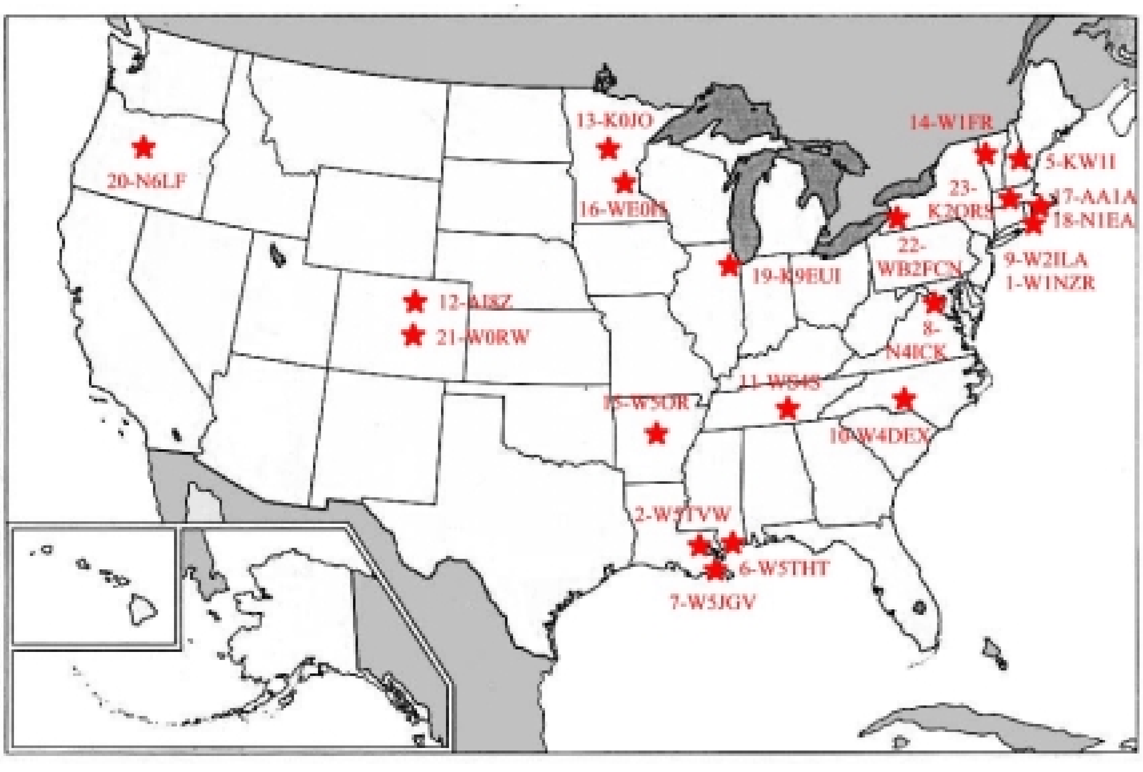

Figure 3. Locations of WD2XSH stations.

Planned activities include:

- CW QSOs,
- CW beacon transmissions, and
- QRSS beacon transmissions.

Tests will be conducted during both daylight and night-time conditions to ascertain capabilities of both ground-wave and sky-wave communication. The initial band plan for experimentation (which may be changed) is given in Table 1.

FREQUENCY, kHz	USE
505.050 - 505.055	QRSS - 0.25-Hz spacing
505.100 - 506.100	CW beacons - 50-Hz spacing
506.5	Rotating beacon, 1-minute time slots
507.5	Calling frequency

Table 1. Band plan for experimental transmissions.

CW is the only transmission mode currently authorized for WD2XSH. CW QSOs will demonstrate the capabilities of amateurs to communicate on this band. PSK-31 and similar modes should provide an even greater communication range for the same signal and noise conditions.

CW beacons enable widespread monitoring of the transmissions. Transmissions typically consist of a repeated pattern like

VVV VVV de WD2XSH/14 14 14

The subband from 505.1 to 506.1 kHz is used for CW beacons. Signals are separated by 50 Hz and stations in proximity are separated by about 200 Hz. A planned "rotating beacon" transmission at 506.5 kHz will place all stations on the same frequency but in different time slots. This will allow receivers to be left on one frequency while the listener monitors or records.

QRSS allows detection of signals with SNRs well below those needed for detecting real-time CW. This makes it a very useful tool for evaluating propagation. The QRSS frequencies are separated by 0.25 Hz so that all QRSS transmissions fit into a 5-Hz bandwidth from 505.050 to 505.055 kHz. This allows a single Argo window to capture all of them at once. In QRSS mode, stations transmit "XSHnn" (with occasional full ID by CW).

The center frequency of 507.5 kHz is the designated calling frequency. The rest of the band is open for use at the discretion of the various station operators.

Participants

The operators have excellent qualifications for participation in this experiment. Most have advanced or extra-class amateur licenses. Most are experienced electronics professionals, and many have maritime-radio backgrounds. Many have operated part-5 or part-15 stations at 137 kHz or 160 - 190 kHz. Many have interests in vintage radio equipment.

Equipment

In the finest tradition of amateur radio, WD2XSH stations are using a wide variety of approaches to produce their signals. Transmitters include state-of-the-art high-efficiency switching-mode power amplifiers, converted amateur gear, test equipment, marine surplus transmitters, and retired NDB transmitters. Antennas range from simple vertical antennas to the classic T to loops. Each station has its own unique equipment and approach.

Future

During the first year, the principal objectives are to get on the air and to prove that we do not create harmful interference. After successfully completing the first season, we will consider requesting modifications in four areas:

- Addition of a small number of participants to expand our coverage, particularly in the southwest, KH6, KL7, and KP4;

- The use of modern narrow-band digital modes such as PSK-31;

- Communication with amateur experimenters in other countries; and

- Emergency-communication tests with historical maritime stations.

5. OTHER MF EXPERIMENTAL STATIONS

The Six-Hundred-Meter Research Group (600MRG) was organized by Ken Gordon W7EKB in 2001. It initially included 35 members at various locations across the USA. In December 2001, the 600MRG was granted experimental license WC2XSR and authorized to use 440, 470, 480, 495, and 166.5 kHz. Several members began experimental transmissions almost immediately. However, within a week or two, the U.S. Coast Guard complained to the FCC and the authorization for 440 - 495 kHz was withdrawn.

U.S. experimental station WA2XRM is located in Colorado Springs, Colorado and operated by Paul Sigornelli, W0RW. It operates on 480 kHz with an ERP of up to 100 W. It has been operating since 2004 and has been renewed through 2009.

Brent ("Gus") Gustafson SM6BHZ received permission from the Swedish Posts and Telecommunications to operate beteen 505.0 and 505.2 kHz with an EMRP of 20 W. This special permission runs from Dec. 1, 2006 to Nov. 30, 2007.

Two German experimental stations are authorized to transmit with an ERP of 9 W. Walter Staubach DJ2LF has been operating DI2AG from Dormitz near Nuernberg since late 2005. Geri Holger DK8KW was issued experimental license DI2BO in 2006. He is located in Peine near Hannover. These stations originally were transmitting on 440 kHz, but were authorized in December 2006 to switch to 505.0 to 505.2 kHz to match the authorization for SM6BHZ.

Interest in experimental or special access to frequencies near 500 kHz has been expressed by the RSGB in the UK, the Irish Radio Transmitters Society, the Wireless Institute of Australia, as well as amateur organizations in New Zealand, Canada, and Belgium.

At the San Marino IARU Region 1 Conference in December 2002, the RSGB presented recommendation REC/02/SM/C4.11 to the HF committee. As a result, a working group was formed to investigate "the possibility of a frequency allocation of approximately 10 kHz between 470 - 490 kHz to investigate propagation and the use of new communication technologies." The IARU Region I continues to coordinate international efforts in this area.

6. FREQUENCY ALLOCATIONS

The current uses of the MF spectrum (Figure 4, Table 1) include nondirectional beacons (NDBs), Differential Global Positioning System (DGPS), NAVTEX. and historical maritime-telegraphy operations. The specific allocations are given in [1].

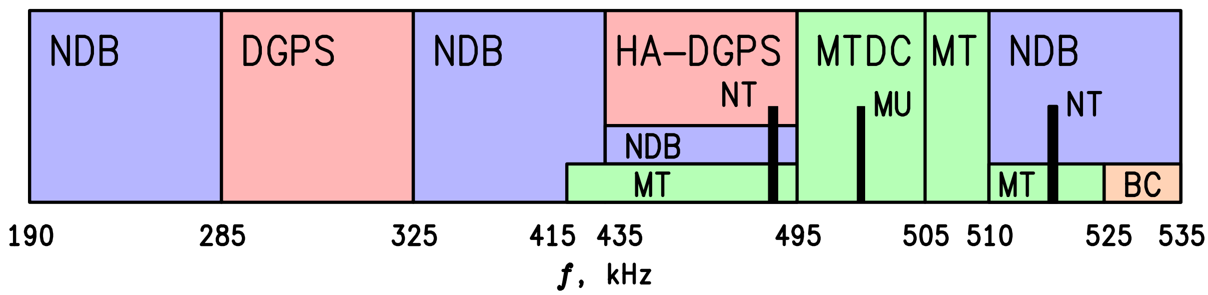

Figure 4. Simplified MF allocations.

BAND REF	FREQUENCY, kHz	USE	USER
A	190 - 285	Aeronautical NDBs	FAA
B	285 - 325	Marine DGPS (NDGPS)	USCG
C	325 - 435	Aeronautical NDBs	FAA
D	435 - 495	High-accuracy DGPS	USCG
E	495 - 505	Maritime calling and distress	Museum
F	505 - 510	Maritime Mobile	None
G	510 - 535	Aeronautical NDBs	FAA
H	490, 518	NAVTEX	USCG

* Used in this note only, not universal.

Table 1. Simplified MF allocations in Region 2.

Aeronautical NonDirectional Beacons

Nondirectional Beacons (NDBs) are the principal occupants of in 190 - 285, 325 - 435, and 510 - 535 kHz (Bands A, C, and G). A few NDBs can also be found in Band D (435 - 495 kHz). A few NDBs in Eastern Europe and Asia can even be found in the distress/calling band (495-505 kHz).

NDBs act as nonprecision approach aids and compass-type locators and are used at ranges up to 50 to 100 mi. They typically transmit an ID via MCW. The FAA currently operates about 225 NDBs [3]. Approximately 50 are operated by the DoD and another 1300 are privately operated. Some NDBs are "stand-alone" types, while others are associated with an Instrument Landing System (ILS).

The Federal Radionavigation Plan (FRP, Section 3.1.9) [3] calls for phasing-out the Federally operated stand-alone NDBs. The phase-out is in progress and will take about ten years. Those NDBs associated with an ILS will continue to be operated until the ILS is retired. Per Section 3.2.7.K of [8], the FAA will have no further use for these frequencies once the NDBs have been decommissioned. However, private operators may continue operation of their NDBs as long as they wish, and it appears that a number of NDBs have been transitioned from FAA to local operation.

Differential Global Positioning System (DGPS)

The marine nondirectional beacons in Band B (285 - 325 kHz) have been phased out and replaced by marine DGPS beacons. In the US, these are also known as National DGPS or NDGPS. They use 200-b/s MSK to relay information from a GPS monitoring station to allow significant improvement in the accuracy of a GPS position fix of a nearby receiver. The format has been standardized by RTCM and DGPS beacons are also found in this band in Regions I and III.

The U.S. Coast Guard (USCG) in cooperation with six other federal agencies such as highways (FHWA) and railroads (FRA) is undertaking a significant expansion of the differential GPS (DGPS) system [2]. This includes a faster data rate (500 or 1000 b/s, vs. the 200 b/s for the DGPS beacons at 300 kHz). The plan is to have coverage from at least two beacons everywhere in CONUS. The higher data rate allows the use of more monitors and the use of carrier phase. This gives them centimeter accuracy and accurate velocity for "real-time kinematics" (RTK). There is a wide variety of applications ranging from tracking vehicles to guiding crop dusters. Many of the applications are for terrestrial navigation such as tracking cars and trains and knowing which lane or track they are on. The MF transmissions are well suited for this because they can be received at all altitudes beyond line of sight. Two such transmitters (Maryland and Virginia, 454 and 456 kHz) have recently been put on the air.

The USCG plans to use the entire Band D from 435 to 495 kHz for these new high-accuracy DGPS beacons. This frequency allocation has been cleared through the NTIA.

Maritime Telegraphy Bands

The frequencies from 435 to 525 kHz were once widely used for maritime telegraphy. The band from 495 to 505 kHz was reserved for calling and distress communication. In Region II, 505 - 510 kHz served as a guard band for the distress/calling band. These frequencies were monitored by both ships and shore stations.

Maritime communication is now handled by HF, VHF, and satellite communication. The Global Maritime Distress and Safety System (GMDSS) [4] has supplanted MF marine telegraphy for both routine and distress communication. Marine telegraphy is no longer used in the Western hemisphere except for by a few “museum” stations. The USCG no longer monitors 500 kHz, nor do the corresponding agencies of most nations.

China and Indonesia remain on the Admiralty List as users, but there are no reports of activity. A number of shore and ship stations retain their licenses for MF. However, none use these frequencies for regular commercial, military, or distress traffic.

The only known users of the distress/calling band (495 - 505 kHz) in Region II are the “museum” stations. The Maritime Radio Historical Society (MRHS) operates KPH and KSM from Bolinas California. The MRHS makes weekly transmissions of weather and other information, calling first on 500 kHz and then transmitting messages on a working frequency. The MRHS has also helped several other stations to resurrect their 500-kHz transmitters. Their annual “Night of Nights” (July 12) commemorates the last commercial telegraphy transmission on 500 kHz in 1999 and several other historical maritime stations sometime participate.

Band E (495 -505 kHz) is allocated for maritime distress and calling. As such, it is subject to special protections embodied in Appendix 13 of the ITU Radio Regulations. Subsection 13 states “... any emission capable of causing harmful interference ... is prohibited.” Subsection 15 further states “Apart from the transmissions authorized on 500 kHz, and taking account of No. 52.28, all transmissions on the frequencies included between 495 kHz and 505 kHz are forbidden. Until 1 February 1999, this applied to frequencies between 490 kHz and 510 kHz.

The prohibitions against other transmissions from 495 to 505 kHz remains in force in spite of the absence of users. However, these regulations have not prevented several NDBs in Eastern Europe and Asia from operating in this band.

Band F (505 - 510 kHz) is allocated for maritime telegraphy in Region II. As noted above, it is no longer subject to the same restrictions as 495 - 505 kHz. Two U.S. NDBs (OF in Norfolk, NE and FA in Fairbanks, AK) operate on 510 kHz and their sidebands extend into Band F. (These assignments are not consistent with the previous prohibition against signals in this band). Otherwise, there are no known users in Region II. In Regions I and III, this band is allocated for NDBs.

NAVTEX

NAVTEX [4] provides automated distribution of weather and navigation-system information to mariners. Worldwide, transmissions are authorized on 490 and 518 kHz, but only 518 kHz is used in the United states. A dozen transmitters provide coverage of most of the coast to a distance of 400 nmi (740 km). NAVTEX uses AMTOR protocol (100-baud FSK 170-Hz shift). NAVTEX broadcasting was implemented between 1983 - 1993 and appears to be mature and stable. Since NAVTEX is part of the GMDSS, it is likely to remain in operation for the forseeable future.

Power-LIne Communication

LF and MF carriers are used on long-distance transmission lines for monitoring and control. These power-line communication (PLC) systems are unlicensed and operate under part 15 of the FCC rules. Their frequencies are no higher than 490 kHz because of prohibitions on incidental radiation in the maritime distress/calling band. In spite of their unlicensed status, concerns about interference to the power grid have caused the FCC to deny access to 137 kHz to US radio amateurs.

7. A NEW AMATEUR BAND

The review of the current uses of the MF band make it clear that the former maritime-telegraphy frequencies from 495 to 510 kHz offer the best and only possibility for a new 600-meter amateur band. Amateur allocations would be on a secondary basis until such time as maritime telegraphy is officially phased-out of the ITU Radio Regulations.

While the ultimate goal is to have at least a secondary amateur allocation recognized by the ITU regulations, it is not necessary to have a change in ITU regulations for amateurs to be allowed to operate. The use of 137 kHz has been authorized in many countries (especially in Europe). However, WRC07 is the first time ITU will discuss officially designating it as an amateur band. Access to 60 meters in the USA and UK is similarly authorized only by the local regulatory agencies (FCC and Ofcom, respectively), and it has no international recognition at this time.

Because power-line carrier systems operate below 490 kHz, interruption of power-company communication should not be an issue as it has been for 137 kHz.

This process will take several years, but it can be done. In 1979, new international amateur allocations were obtained at 30, 24, and 17 meters. Recent national authorizations in the US and UK permit operation on 60 meters. The 137-kHz (2200 meters) should soon be officially recognized by ITU.

Region II

ITU regulations preserved 505 - 510 kHz as a guard band for the distress/calling band from 495 - 505 kHz. As a result, it remains unused today. This band is the obvious choice for a amateur allocation in Region II.

The WD2XSH stations are now demonstrating that there is no harmful interference caused by amateur operations in this band. After perhaps two years of such experimental operations, it should be possible to petition the FCC for amateur access to this band. This process should be similar to that used to gain access to the 60-meter band.

The two NDBs operating on 510 kHz must be protected from interference. Since NDBs are used only over a range of 50 to 100 mi, their signals are relatively strong in the regions of use. In fact, many NDBs share the same or adjacent frequencies (Appendix C). Exclusion zones from 508 to 510 kHz with radii of 200 to 300 mi around these NDBs will provide sufficient protection.

International

Internationally, the situation is more complicated.

In Regions I and III, the band from 505 to 510 kHz is allocated for NDBs. However, usage of this band by NDBs is generally light and limited to Eastern Europe (Appendix D). It should be feasible for amateurs to use this band, at least in many countries, by establishing exclusion zones around these NDBs.

Overall, the best option for an international amateur allocation is distress/calling band 495 - 505 kHz. The only current users are historical maritime "museum" stations, and they operate only on 500 kHz or working frequencies well outside of 495 - 505 kHz. The maritime historical stations make light use of the band, and currently operate under maritime licenses. Amateurs would have secondary status and therefore be obligated to avoid interference.

Appendix 13 of the ITU Regulations has preserved this band from other interests. However, since there is no longer any emergency communication on 500 kHz to be protected, Appendix 13 is now an anacronism. An initiative to remove Appendix 13 should be launched simultaneously with efforts to obtain allocations for amateurs and muesum stations.

It should be noted that Appendix 13 has not stopped some Eastern European NDBs from operating in this band. Regardless of the legitimacy of the frequency assignment, an exclusion of 200 to 300 mi will suffice to avoid interference.

It may prove expedient to work initially toward this allocation through CEPT and local regulatory agencies rather than the ITU. Results from experimental operations in the UK and possibly elsewhere will demonstrate noninterference.

Modulation Modes, Band Plan, and Uses

The limited spectrum available precludes the use of AM, SSB, AMTOR, and other wideband modes except perhaps for special events. Modulation modes suitable for a 600-meter amateur band are CW (including QRSS) and narrowband digital modes such as PSK-31, FSK-31, and MSK-31.

To make the best use of the limited spectrum available, it will be necessary to develop a band plan that separates QRSS beacons, CW beacons, CW QSOs, and PSK-31 operations. To facilitate sharing of this band with the museum stations, the band plan should reserve 499 to 501 kHz for museum-radio operations, amateur emergency communications, and amateur special events.

The need to make or to adapt equipment and the larger antennas required make it unlikely that a 600-meter amateur band will become anything close to as popular as the HF bands. The author anticipates that it will be occupied by a combination of experimenters and amateurs with historical interests and ties to maritime radio. Given the limited spectrum available, it will be best to exclude 600 meters from contest operations.

Special Events

The 600-meter amateur band will be an ideal place for special events of a historical nature. One example is a Fessenden commemoration on Christmas Eve during which AM would be permitted. Another example is a maritime commemoration (on November 3 to mark the anniversary of the Berlin Convention that created SOS and the 500-kHz distress/calling band). During this event, MCW transmission and cross-service contacts with museum stations would be permitted.

Threats

This part of the radio spectrum may be of interest to other users, including commercial HADGPS, NAVTEX, broadcasting, and traffic-information systems. Since the spectrum from 435 to 495 kHz is at present little used and many NDBs in the band from 510 to 530 kHz will soon be decommissioned, there is no real need for any of these services to use 495 - 510 kHz.

8. MUSEUM STATIONS

Maritime communication has been an important part of radio since the beginning, and amateur and maritime communication have much common history. Museum operations such as those of the Maritime Radio Historical Society (MRHS) preserve an important part of our history in a manner that allows it to be seen in operation rather than simply on display. This is analogous to a living-history museum or an operating steam railroad.

The museum operators currently operate under maritime "coast station" licenses. At some point, a regulating agency will no doubt challenge the legitimacy of these stations as providing real maritime communication and refuse to renew their license.

To address this problem, the author recommends the creation of a new "museum radio service" with a secondary allocation from 495 to 505 kHz. The requirements for a license for this service should include operation by a bona-fide nonprofit organization, operation of historical equipment, and operation according to historical procedures.

Regardless of the type of license, the limited use of the 600-meter band by museum stations alone is not likely to preserve the band against commercial and government uses. Sharing the band with amateurs will, however, greatly expand its use and open the door for organizations such as ARRL and RSGB to defend the band against intruders. It will also ensure that CW will continue to be heard on 600 meters. Thus it is essential for the amateurs and museum operators to work together. As noted above, a simple band plan will eliminate interference problems.

Another area for cooperation is emergency communication. The higher-power transmitters of the museum stations could also serve as important nodes in an amateur ground-wave emergency network. Providing emergency communications is an important reason for both services to occupy - and to share - the 600-meter band.

9. CONCLUSION

It seems fitting that a hundred years after 500 kHz was designated the international distress frequency, we are working to find new uses for the band for emergency communication as well as experimentation. We are looking forward to applying modern technology to this historic part of the spectrum, and to working with the maritime historical groups to see that it is preserved.

10. REFERENCES

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[6] L. Boithias, *Radiowave Propagation*. New York: Wiley, 1987.

[7] A. D. Spaulding and J. S. Washburn, "Atmospheric radio noise: World- wide levels and other characteristics," Report 85-173 (PB85-212 942), National Telecommunications and Information Administration, Boulder, CO, April 1985.

[8] “2001 Federal Radionavigation Plan," U.S. Department of Transportation and U. S. Department of Defense, document DOT-VNTSC-RSPA-01-3.1/DOD-4650.5, Dec. 2001. Available from http://www.navcen.uscg.gov/pubs/frp2001/.

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APPENDIX A. SNR PREDICTIONS

The SNR of a ground-wave signal depends upon a combination of

- Antenna gain,
- Surface-wave attenuation, and
- Atmospheric-noise level.

Figure 5 shows these effects as a function of frequency for communication over a range of 200 km.

The predictions used in this note (Figure 2 and Figure 5) are based upon the following:

- 15-m (50-ft) monopole with sixteen 30-m radials,
- Ground with σ = 0.01 S/m and ε_r = 10,
- 1 W delivered to the antenna,
- 1-Hz bandwidth,
- Median atmospheric-noise factor for fall and spring (70 dB), and
- Median atmospheric-noise level (50-percent).

Antenna gain is predicted by simulation with the Numerical Electromagnetics Code [5]. The gain increases with the square of frequency until the electrical length becomes a significant part of a wavelength. This holds for any electrically short antenna. The predicted antenna gain at 500 kHz is -15 dBi.

The amplitude of the surface wave is then predicted by a combination of standard Sommerfeld and spherical-earth theory [6]. The noise levels are based upon standard tables [7]. As shown, the combination of antenna gain, surface-wave attenuation, and noise level favors frequencies near 500 kHz for distances from 100 to 300 km.

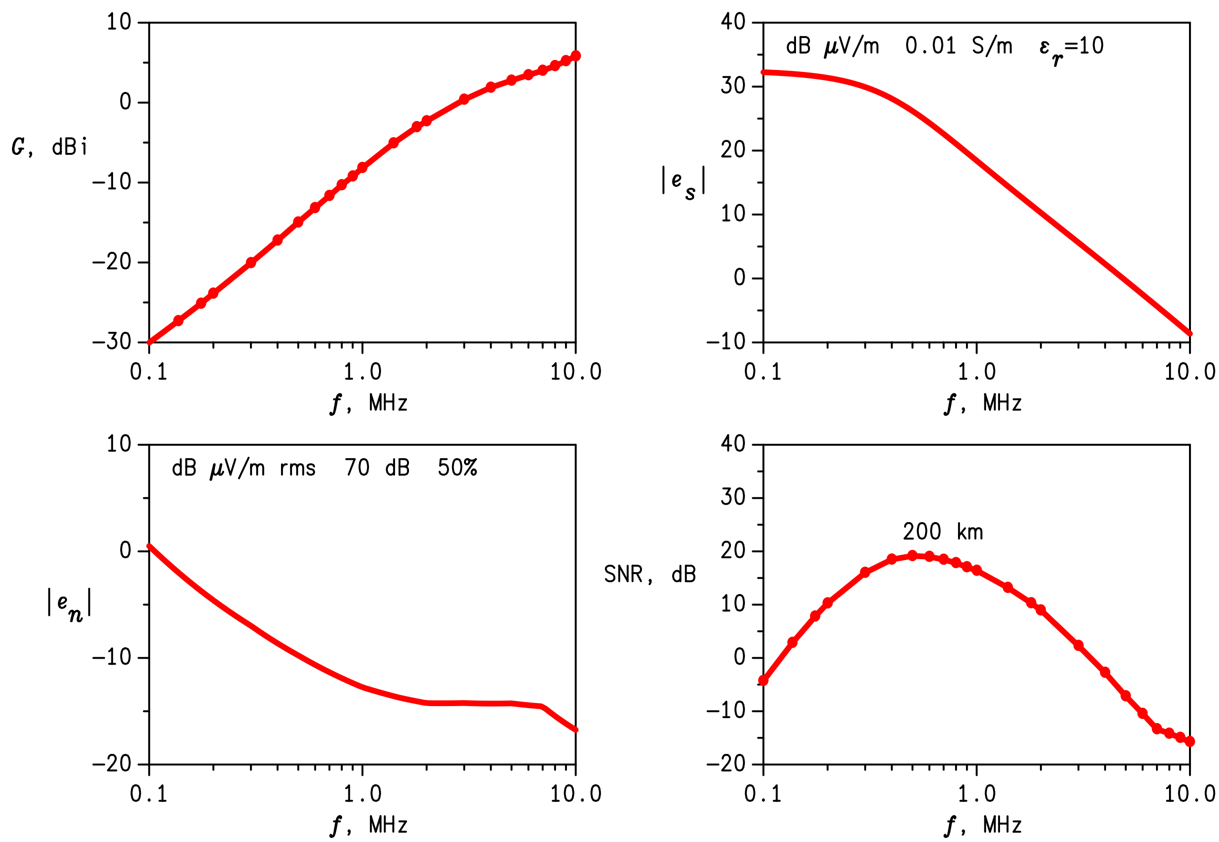

Figure 5. Factors contributing to the SNR of a ground-wave signal.

APPENDIX B. WD2XSH STATIONS

STATION	HAM CALL	NAME	LOCATION
WD2XSH/1	W1NZR	Brown Beezer	Jamestown, RI
WD2XSH/2	W5TVW	Sandy Blaize	Hammond, LA
WD2XSH/5	KW1I	Dale Gagnon	Bow, NH
WD2XSH/6	W5THT	Pat Hamel	Long Beach, MS
WD2XSH/7	W5JGV	Ralph Hartwell	Jefferson, LA
WD2XSH/8	N4ICK	André Kesteloot	McLean VA 22101
WD2XSH/9	W2ILA	Tom Mackie	Jamestown, RI
WD2XSH/10	W4DEX	Joe McIntyre	Stanfield NC
WD2XSH/11	WS4S	Conard Murray	Cookeville, TN
WD2XSH/12	AI8Z	Mike Mussler	Nederland, CO
WD2XSH/13	K0JO	John Oehlenschlager	Verndale, MN
WD2XSH/14	W1FR	Fritz Raab	Colchester, VT
WD2XSH/15	W5OR	Don Reaves	Roland, AR
WD2XSH/16	WE0H	Mike Reid	St. Francis, MN
WD2XSH/17	AA1A	Dave Riley	Marshfield, MA
WD2XSH/18	N1EA	David Ring	Green Harbor, MA
WD2XSH/19	K9EUI	Bob Roehrig	Batavia, IL
WD2XSH/20	N6LF	Rudy Severns	Cottage Grove, OR
WD2XSH/21	W0RW	Paul Signorelli	Colorado Springs, CO
WD2XSH/22	WB2FCN	James Walker	Buffalo, NY
WD2XSH/23	K2ORS	Warren Ziegler	Wayland, MA

APPENDIX C. NORTH AMERICAN NDBS NEAR 500 kHz

From airnav.com, worldaerodata.com, and classaxe.com

f, kHz	ID	LOCATION	OPERATOR
492	E8	Davis Inlet, NFLD	
510	OF	Norfolk, NE	FAA
510	FA	Fairbanks, AK	FAA
512	HMY	Lexington, OK	?
513	PP	Omaha, NE	?
515	RRQ	Rock Rapids, IA	Local possibly off air

515	ONH	Jefferson City, MO	FAA
515	SAK	Kalispell, MT	FAA
515	OS	Columbus, OH	FAA
515	PN	Ponca City, OK	FAA
515	PKV	Port Lavaca, TX	Local
515	CL	Port Angeles, WA	FAA
516	YWA	Petawawa, ONT	RCAF
517	FN	Clinton, IA	
517	GKB	Kansas City, MO	
518	GCT	Guthrie Center, IA	Local
519	IQS	Sallisaw, OK	Local
520	F9	Miramichi, NB	
520	IQS	Sallisaw, OK	
521	ORC	Orange City, IA	Local
521	TVX	Greencastle, IN	Local
521	TO	Topeka, KA	FAA
521	FEU	Frankfort, KY	Local
521	INE	Missoula, MT	FAA
521	DWH	Houston, TX	Local
521	GF	Cleveland, OH	
521	GM	Greenville, SC	
523	JJH	Johnstown, NY	Local
524	MNL	Mineral Creek AK	FAA
524	UOC	Iowa City, IA	Local
524	AJG	Mt. Carmel IL	Local
524	HEH	Newark, OH	Local
524	HRD	Kountze Silsbee, TX	Local
525	ICW	Nenana AK	FAA
526	RWE	San Miguel, CA	
526	OJ	Olathe, KS	
526	ZLS	Stella Maris, Bahamas	USCG
529	SQM	Sumner Strait, AK	FAA
529	FDV	Ft. Davis, AK	FAA
530	ADK	Adak Island, AK	FAA

APPENDIX D. NDBS HEARD IN EUROPE

From http://www.classaxe.com/dx/ndb/rna/index.php, Nov. 2006. Unidentified stations (possibly military) are not included.

f, kHz	ID	LOCATION
495	PA	Pancevo, Serbia
495	HU	Engels, Russia
495	ZK	Engels, Russia
495	ZK	Engles, Russia
496	ER	Yerevan, Russia
497	QZ	Bolshaya Murta, Russia
499.3	BDN	Pirate station heard in Europe
507	ND	Bolshevic, Russia
508	Z	Zilina/Hlinik, Slovakia
509	K	Mykolaivka, Ukraine
509	M	Taraz, Kazhakistan
509	R	Chernivtsi, Ukraine
510	CE	Poltava, Ukraine
510	CR	Cheboksary, Russia
510	DU	Tokol, Hungary
510	LA	Cheboksary, Russia
510	LJ	Gromovo, Russia
510	MB	Poltava, Ukraine
510	NK	Novokazalinsk, Kazakhistan