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RN04-5

A 600-meter amateur band

by

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March 11, 2004
Revision A: April 18, 2004

Abstract

A 600-meter (500-kHz) band will 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 frequency band from 495 - 510 kHz is recommended, as it is no longer used for maritime telegraphy in the western hemisphere, has not yet been claimed by another service, and is not used for power-line communications. A group of experimenters is applying for part-5 experimental licenses for these frequencies. The ARRL is encouraged to begin work toward obtaining an amateur allocation in this frequency range before another entity lays claim to the unused frequencies.

Indexing Terms

Radio, amateur
Communication, MF

1. INTRODUCTION

This note provides an overview of a new 600-meter (500-kHz) amateur band. Included here are:

- Characteristics and advantages,
- Frequencies and interference,
- Experimental licenses,
- ARRL involvement, and
- Historical perspective.

2. CHARACTERISTICS, ADVANTAGES, AND USES

A frequency allocation at 600 meters (500 kHz) will offer a number of unique opportunities and capabilities to the amateur service, including both

- Ultra-reliable regional ground-wave communication, and
- Experimentation with antennas, propagation, modulation, and signal processing for MF.

Ultra-Reliable Emergency Communications via Ground Wave

Ground-wave (also called "surface-wave") propagation at low and medium frequencies can provide reliable communication over medium and large 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) occurs in the range of 400 to 600 kHz, as shown in Figure 1. The 600-m amateur band is therefore ideal for amateur ground-wave emergency communications.

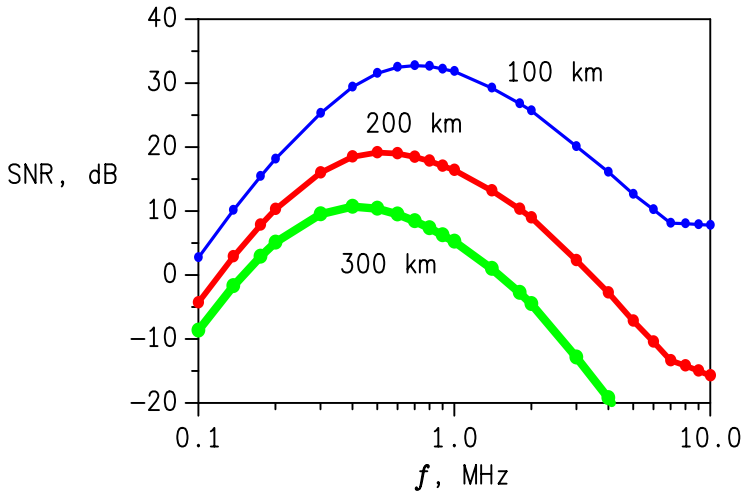

Figure 1. Ground-wave SNR as a function of frequency for typical amateur use.

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 40-50-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 skywave (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.

Experimentation

The 600-meter band will also give amateurs several unique opportunities for experimentation, including:

- Electrically short antennas,
- Propagation,
- Modulation techniques, and
- Signal processing.

Operation on this band will motivate experiments to produce electrically short antennas that are efficient and transportable. It will afford a chance to experiment with both long-range

ground-wave propagation as well as D-layer propagation effects, neither of which is possible on higher-frequency amateur bands.

The need for reliable digital communication on this band is expected to motivate experimentation not only with existing digital modes, but also modulation techniques such as minimum-shift keying (MSK), which is efficient both in the use of bandwidth and power. Development of protocols for adaptation of data rates to the SNR will also be needed so that the emergency-communication systems can move data faster when noise levels are lower. The 600-meter band will also present new challenges for signal processing, including optimum nonlinear processing of atmospheric noise and adaptive cancellation of man-made noise and interference.

3. FREQUENCIES

The uses in Region 2 of the LF and MF spectrum immediately below the BC band are summarized in Table 1. The specific allocations are given in [1]

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

Table 1. Simplified LF/MF allocations in Region 2.

Differential Global Positioning System (DGPS)

The marine nondirectional beacons in Band B have been phased out and replaced by DGPS beacons. These transmissions relay information from a GPS monitoring station to allow significant improvement in the accuracy of a GPS position fix of a nearby receiver.

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 chief of the Navigation Technology Branch at the U.S. Coast Guard Navigation Center (NAVCEN) advises that they plan to use the entire Band D from 435 to 495 kHz for these new high-accuracy DGPS beacons. This frequency allocation was obtained through NTIA and it is unlikely that any attempts for either new experimental licenses or an amateur allocation in this frequency band would be successful.

Aeronautical NonDirectional Beacons

Nondirectional Beacons (NDBs) in Bands A, C, and G act as nonprecision approach aids and compass-type locators. The FAA currently operates over 700 NDBs. approximately 200 are operated by the DoD and another 800 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 stand-alone NDBs. This is scheduled to begin in 2010 and will take about five years. Those NDBs associated with an ILS will continue to be operated until the ILS is retired.

At present, any attempt for experimental licenses or secondary amateur use of these bands will immediately run into flight-safety issues. If the NDBs are phased out by 2005 as planned, some parts of these bands may become available. However, ILS-associated NDBs will continue to operate and the phase-out of other NDBs may be delayed.

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. 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 occasional special-event transmissions. The USCG no longer monitors 500 kHz, nor do most nations.

A number of shore stations retain their licenses. However, the only signal reported in the remaining marine telegraphy band (Bands E and F) by the 600MRG (see next section) in the past three months is a special-event transmission by marine shore station KPH in Bolinas, CA. Another special-event transmission is scheduled for late May-June 2004 in connection with the cruise of the LST Memorial Ship *LST 325*. Loggings in the *Lowdown* for the past year report no other activity in Region 2.

The USCG has stated that it has no interest in these bands, nor any objection to their use for experimental or amateur service. The FAA does not appear to have an immediate interest in these bands, nor does the current allocation fit their use.

It is possible that some 500-kHz systems remain in use in Regions 1 and 3. However, use of 500 kHz in those regions is certainly declining and will eventually cease. For example, the

Italian government ceased monitoring of 500 kHz at the end of 2003. Thus this band has the potential to become an international allocation.

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. Use of this band would require protection of NAVTEX transmissions at 518 kHz. This could be done by regional power/operating restrictions in the band from 517 to 519 kHz.

Recommendation

The marine-telegraphy bands from 495 to 510 kHz are currently unused and the obvious choice for experimental licenses and a new amateur band. There should be no objection to the use of Band F (505 to 510 kHz). While Band E (495 - 505) is similarly unused, there may be some objection to its use because of the possibility that legacy 500-kHz equipment could be used for an emergency transmission. This objection should fade rapidly over the next few years. A reasonable approach may be to ask for the band edges first and the band center later.

Experimental and amateur use of these frequencies will ensure that they are monitored regularly. Since government agencies are no longer monitoring this band, experimental and amateur use would actually improve the odds of reception of an emergency transmission on 500-kHz. Interference to those systems is expected to be minimal to nonexistant because of (a) the relatively high power of those stations and (b) the distance.

Perhaps a decade or so in the future, it may be possible to expand into Band G (510 to 535 kHz) as NDBs in that band are decommissioned.

4. EXPERIMENTAL LICENSES

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 USCG complained to the FCC and the authorization for 440 - 495 kHz was withdrawn. One 480-kHz experimental beacon, WA2XRM (operated by W0RW) continues to operate, but that authorization expires at the end of the year. A few members operate experimental transmitters on 166.5 kHz, but many others were primarily interested in 600 meters. The 600MRG is now preparing a modification to its license to use the 505-510-kHz band and the edges of the 495-505-kHz band. A dozen more members will be added to the license at a later date. About half a dozen members have 500-kHz equipment ready to go as soon as a license is granted. Another dozen should be on the air within a short

period thereafter. Experimental use by this group should establish positively that there is no interference problem with other services.

5. OBTAINING A NEW AMATEUR BAND

The preceding discussion has shown that

- A 600-meter amateur band will offer unique opportunities for emergency communication and experimentation,
- The maritime-telegraphy band from 495 to 510 kHz is virtually unused, and neither the US Coast Guard nor FAA currently are interested in it, and
- There is interest in such a band, as a group of experimenters is ready to put transmitters on the air under part 5.

In addition,

- An amateur allocation is the only way to ensure access to the 600-meter band on a permanent basis.
- Access by US amateurs to the amateur band at 137 kHz is not likely to be granted for a number of years until experimental licensees prove that they do not disrupt power-line communication (PLC), and
- Interference with power-line communication is not an issue for the 600-meter band, as the highest frequency used in PLC is 490 kHz.

The ARRL is therefore strongly encouraged to begin work to obtain an amateur 600-meter band. ARRL involvement is essential to this quest for two reasons:

- ARRL personnel have experience in dealing with the FCC, WRC, and other administrative bodies and procedures, and
- A petition from ARRL will carry far more weight than petitions from the 600MRG, AMRAD, and individuals.

Frequencies

The band from 495 to 510 kHz is currently allocated on a primary basis to maritime telegraphy. The author recommends seeking secondary status (no harmful interference to existing marine telegraphy) for amateurs in the entire 495-to-510-kHz band. The petition should divide the band into three segments:

- 505 - 510 kHz,
- 495 - 497.5 and 502.5 - 505 kHz, and
- 497.5 - 502.5 kHz.

Little if any concern is expected for the 505 - 510 kHz band. Since the band from 495 to 505 kHz was once used for distress communication, there may be some concerns about legacy operators using these frequencies. The division into three subbands will allow setting different lower power levels and/or phasing-in access to protect any possible legacy users in the 495 to 505 kHz band.

At a later date, we will need to track the FAA's plans for decommissioning the NDBs. Sometime after 2010, we may be able to add 510 – 525 kHz to the 600-meter amateur band.

Modulation Modes

The anticipated modulation modes are CW and narrow-band digital. Voice transmission does not seem appropriate given the limited size of the band.

Uses

Given the limited frequency range available, consideration should be given to limiting the uses of the band (at least initially) to experimental and emergency communication. The exchange of signal reports, locations, and equipment characteristics should be considered a legitimate part of experimentation. However, rag-chewing and contesting should be avoided.

Prompt Action Imperative

When the author first began monitoring these bands in 2000, the band from 435 to 495 kHz was essentially unused. It has since been acquired by the US Coast Guard for their HA DGPS service. The unconfirmed report of an MSK transmission on 504.5 kHz is a reminder that some one else will find a use for these frequencies if they are not acquired for amateur use.

Now is the ideal time for the ARRL to take action to convert these frequencies into an amateur band. The US Coast Guard has yet to fill the 435 - 495-kHz band with DGPS beacons and is not yet looking for more spectrum. The FAA is not currently planning any other use for its LF/MF bands. The demise of maritime telegraphy has left the band from 495 to 510 kHz virtually unused. Thus we have a brief window of opportunity to try to acquire these frequencies for the amateur service before someone else does so.

International Interest

In response to a suggestion by the RSGB at the 2003 IARU Region 1 conference, the IARU formed a working to study the issues relating to an amateur band near 500 kHz.

6. HISTORICAL PERSPECTIVE

Maritime telegraphy in the 500-kHz band has been used almost since inception of radio communication. A transition to amateur service would allow it to become a working monument

that preserves the traditions of telegraphy and emergency communication. Amateurs using a new 600-meter band will welcome special-event transmissions from stations such as KPH. It may even be possible on special occasions to arrange for cross-service communication between amateurs and legacy maritime stations such as KPH (much as is done with DoD stations on Armed Forces Day).

7. REFERENCES

[1] 47CFR2.106, available at http://www.fcc.gov.

[2] Meetings of the Civil Global Positioning System Service Interface Committee (CGSIC). http://www.navcen.uscg.gov/cgsic/meetings.

[3] "2001 Federal Radionavigation Plan," U.S. Department of Transportation and U. S. Department of Defense, document DOT-VNTSC-RSPA-01-3/DOD-4650.5, Dec. 2001. Available from http://www.navcen.uscg.gov/pubs/frp2001/.

[4] "Global Maritime Distress and Safety System," U.S. Coast Guard, http://www.navcen.uscg.gov/marcomms/gmdss.

[5] *The Numerical Electromagnetics Engineering Design System*. Monterey, CA: The Applied Computational Electromagnetics Society, 1989.

[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.

APPENDIX. SNR PREDICTIONS

The SNR prediction (Figure 1) is based upon a combination of three factors. Antenna gain is predicted by simulation with the Numerical Electromagnetics Code NEC2 [5]. The amplitude of the surface wave is then predicted by a combination of standard Sommerfeld and spherical-earth theory [6]. Noise levels are based upon standard tables [7].

The specific parameters for this plot are:

- 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,
- Median atmospheric-noise factor for fall and spring (50 dB), and
- Median atmospheric-noise level (50-percent).

The predicted antenna gain at 500 kHz is -15 dBi.