Spread Spectrum: Buaas SS STA and Waiver 1992-1997

A **Special Temporary Authorization (STA)** is the authority granted to a permittee or licensee to permit the operation of a broadcast facility for a limited period at a specified variance from the terms of the station authorization or requirements of the FCC rules applicable to the particular class of station. Here is the complete text of Title 47 Section 73.1635 taken from the Code of Federal regulations.

History of the Buaas Amateur Spread Spectrum STA

On June 11, 1991 Robert Buaas, K6KGS, requested a waiver of the rules and regulations governing Amateur spread spectrum communications. This is the original request sent to the FCC.

On April 17, 1992, the FCC granted the STA.

In March 31, 1993 Robert Buaas requested an extension to the Amateur Spread Spectrum STA. On May 26, 1993, the FCC granted a one year extension to the STA.

On April 30, 1994 Robert Buaas made a third request to extend the Amateur Spread Spectrum STA. In this request he includes results from the experimentation conducted during the STA and recommended extending the STA indefinitely or until a rules change is made in the interest of minimizing paperwork.

On December 27, 1994, the FCC granted an indefinate STA and waivers until completion of data communications experiments.

The Original Request for the Special Temporary Authority (STA)

20271 Bancroft Circle
Huntington Beach, CA 92646
June 11, 1991

Mr. Ralph A. Haller, Chief
Private Radio Bureau
Federal Communications Commission
Washington, DC 20554

Dear Mr. Haller:

The Commission is requested to grant special temporary authority (STA) to permit experimental data communications in the amateur service as detailed below. The application is made on behalf of, and with the consent of, the individuals named herein.

NAMES AND ADDRESSES OF THE APPLICANTS

The names, addresses and telephone numbers (day and night) of the proposed participants are given in the Annex A. We request the ability to add participants upon specific prior coordination of the undersigned. A complete, updated list of participants will be mailed to the designated Commission office monthly.

BACKGROUND AND HISTORY

The undersigned is a member of the Amateur Radio Research and Development Corporation (AMRAD) and participated in the 1984 STA granted to AMRAD which ultimately resulted in spread spectrum modulation being authorized in the Amateur Radio Service. At the time the rules were rewritten, certain spreading sequence equations and specific procedures were specified. In the time since, Code Division Multiple Access (CDMA) has gained some favor for its potential for "coding gain" as well as "spreading gain." Custom designs for VLSI gate array integrated circuits have made inexpensive implementations possible for digital matched filters required in these systems. This type of digital baseband direct-sequence spread spectrum (DSSS) component is capable of having spreading sequences loaded from an external supervisory processor.

Also, recent inexpensive surface acoustic wave (SAW) matched filters have become available which are suitable for both generating and demodulating DSSS signals.

DESCRIPTION OF NEED

An STA is needed to permit operation until such time that a permanent rule change becomes effective.

TYPE OF OPERATIONS

An m-sequence implemented as specified in paragraph 97.311(d)(1) will be used as a "generating function." Spreading codes will be selected from continuous segments of bits produced in the output of the generating function based on their suitability to provide uniformly distributed spectral density, code orthogonality and maximal coding gain. Each spreading code will represent one symbol in the data to be transmitted. Only the selected spreading codes will be transmitted, and each will be transmitted in its entirety.

DSSS generators using SAW devices with fixed spreading codes not related to the m-sequences specified in paragraph 97.311(d)(1) will also be used.

Frequency hopping may be evaluated as a means for further distributing the transmitted energy.

Frequency synthesized homodyne and single heterodyne transceivers will be evaluated on each of the frequency bands proposed, time and resources permitting. Test units will also be made available for FCC monitoring if so requested.

Purpose:

The purpose of the tests is to experiment with spread spectrum transmission, reception and processing techniques.

Objectives:

Specific objectives of the STA are to:

(1) assess the strengths and weaknesses of the proposed systems;
(2) evaluate the potential of spread spectrum overlay on conventional FM systems;
(3) determine interference impact, if any, to existing users;
(4) evaluate immunity to intersymbol interference due to multipath propagation;
(5) evaluate potential for improved spectrum utilization;
(6) evaluate performance improvement claimed for CDMA; and,
(7) gain operational experience.

DATES AND TIMES OF OPERATION

The applicants request that operation under the STA commence immediately upon the granting of authority by the Commission, and that such authority be permitted for one year, with leave to renew the STA.

CLASS OF STATIONS AND RADIO SERVICE

All stations are licensed in the Amateur Service, and all licensees hold a minimum of a Technician class license.

LOCATIONS

The locations of the stations shall be from the fixed station location listed on the station licenses of the applicants, plus such portable operation as would be permitted under ordinary amateur operation.

NUMBER OF TRANSMITTERS

Each station will use one transmitter per frequency band in use.

OPERATING FREQUENCIES

Operating frequencies will be as follows: 50-54 MHz, 144-148 MHz, 222-225 MHz, 420-450 MHz, 902-928 MHz, 1240-1300 MHz and 2390-2450 MHz.

OUTPUT POWER OF TRANSMITTERS

The maximum power will not exceed 100 watts.

TYPE OF EMISSION

Spread spectrum emissions are to be used.

DESCRIPTION OF ANTENNA

No special waiver of the rules is requested. Antennas expected to be used are dipoles, collinear arrays and Yagi arrays with gains of 0 to 12 dBi, at heights up to 30 meters above ground.

WAIVERS REQUESTED

Waivers of the following sections of the rules are requested:

97.305(c) Column entitled "Emission types authorized" is requested to be waived in order to transmit emission type SS in the bands 6 m, 2 m and 1.25 m.

97.311(c) is requested to be waived to lift the prohibition against hybrid SS transmissions.

97.311(d) is requested to be waived to permit the use of other spreading codes.

SUMMARY

The undersigned on behalf of the group of experimenters respectfully requests that the Commission grant this request for special temporary authority. If you have any questions or need additional information, please contact the undersigned.

Sincerely,

/S/ Robert A. Buaas, K6KGS

First Response

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554
April 17, 1992

Mr. Robert A. Buaas
20271 Bancroft Circle
Huntington Beach, California 92646

Dear Mr. Buaas:

This is in response to your request for special temporary authority (STA) and waiver of the Commission's rules in order to permit certain amateur stations to conduct experiments involving Code Division Multiple Access (CDMA) spread spectrum (SS) emissions. Attached to your request are individual requests from the participating station licensees.

Your suggestion was presented to the Frequency Assignment Subcommittee of Interagency Radio Advisory Committee, which concurred with your proposal without objections. Accordingly, an STA is granted for a period of 365 days commencing with the date of this authorization for the amateur stations listed on the enclosure submitted with you letter of June 11, 1991, to the Chief, Private Radio Bureau. During this time, Section 97.305(c) of the Commission's Rules, 47 C.F.R. Section 97.305(c), is waived to the extent that these particular amateur stations are authorized to transmit SS emissions on frequencies in the bands 50 MHz to 54 MHz, 144 MHz to 148 MHz, and 222 MHz to 225 MHz; Section 97.311(c) of the Commission's Rules, 47 C.F.R. Section 97.311(c) is waived for these stations to the extent that the prohibition against hybrid SS emissions is lifted; and Section 97.311(d) is waived for these stations to use other spreading codes.

The above authorization will also apply to any additional amateur stations joining the project during the period of the STA, provided you submit an amended list and individual requests to Robert H, McNamara, Chief of Special Services Division at:

Federal Communications Commission
Private Radio Bureau
2025 M Street, N.W., Rm. 5322
Washington, D.C. 20554

Sincerely,

/S/ Ralph A. Haller
Chief, Private Radio Bureau

Second Response

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554
May 26, 1993

Mr. Robert A. Buaas
20271 Bancroft Circle
Huntington Beach, California 92646

Dear Mr. Buaas:

This is in response to your request dated March 31, 1993 for special temporary authority (STA) and waiver of the Commission's rules in order to permit certain amateur stations to continue to conduct experiments involving Code Division Multiple Access (CDMA) spread spectrum (SS) emissions. Your letter also requests the Commission to designate a point of contact to aid in developing possible rules changes that will preclude the need for future waivers of this nature.

Your suggestion was presented to the Frequency Assignment Subcommittee of Interagency Radio Advisory Committee, which concurred with your proposal without objections. Accordingly, an STA is granted for a period of 365 days commencing with the date of this authorization for the amateur stations listed on the enclosure submitted with you letter of June 11, 1991, to the Chief, Private Radio Bureau. During this time, Section 97.305(c) of the Commission's Rules, 47 C.F.R. Section 97.305(c), is waived to the extent that these particular amateur stations are authorized to transmit SS emissions on frequencies in the 6 meter(m) (50 MHz to 54 MHz), 2m (144 MHz to 148 MHz), and 1.25m (222 MHz to 225 MHz) bands; Section 97.311(c) of the Commission's Rules, 47 C.F.R. Section 97.311(c) is waived for these stations to the extent that the prohibition against hybrid SS emissions is lifted; and Section 97.311(d) is waived for these stations to use other spreading codes.

The above authorization will also apply to any additional amateur stations joining the project during the period of the STA, provided you submit an amended list and individual requests to Robert H, McNamara, Chief of Special Services Division at:

Federal Communications Commission
Private Radio Bureau
2025 M Street, N.W., Rm. 5322
Washington, D.C. 20554

The point of contact regarding proposals for rules changes related to amateur service matters is the Personal Radio Branch at the address indicated above.

Sincerely,

/S/ Ralph A. Haller
Chief, Private Radio Bureau

Request for extension including results of experimentation

20271 Bancroft Circle
Huntington Beach, CA 92646
April 30, 1994

Mr. Ralph A. Haller, Chief
Private Radio Bureau
Federal Communications Commission
Washington, DC 20554

Dear Mr. Haller:

The Commission is requested to extend the special temporary authority (STA) granted by your office May 26, 1993, to continue experimental data communications in the amateur service using Spread Spectrum Modulation.

Our work to date has focused on determining:

a) what performance can be achieved utilizing several techniques in spectra already occupied by narrowband emitters,
b) what level of interference results to existing users,
c) what impact existing usage has on degrading SS performance,
d) how much usage can be pressed into a given spectrum using CDMA, and
e) what proposals we might make to change the Rules and thereby further encourage experimentation without the need for this STA.

Please find attached the report of our work and findings to date, submitted to the ARRL Digital Communications Committee in December, 1993. Our report resulted in an ARRL Board of Directors resolution to prepare and submit a formal request to change the Part 97 Rules. ARRL established a working committee to further study the details of our rules change proposal.

We are well into the design portion of the 6 meter experiment described near the end of the report. The work has progressed more slowly than hoped, due largely to the fact that we must continue to earn our livings. Would the Commission entertain the request to grant this extension for a period longer than one year, in the interest of minimizing paperwork? If so, we could continue our work until the rules change cycle were completed.

Sincerely,

/S/ Robert A. Buaas, K6KGS

Spread Spectrum Special Temporary Authority (STA)
Project Results and Recommendations

Background

The undersigned is a member of the Amateur Radio Research and Development Corporation (AMRAD) and participated in the 1984 STA granted to AMRAD which ultimately resulted in spread spectrum modulation being authorized in the Amateur Radio Service. At the time the rules were rewritten, certain spreading sequence equations and procedures were specified. In the time since, Code Division Multiple Access (CDMA) has gained some favor for its potential for "coding gain" as well as "spreading gain." Custom designs for VLSI gate array integrated circuits have made inexpensive implementations possible for digital matched filters required in these systems. This type of digital baseband direct-sequence spread spectrum (DSSS) component is capable of having spreading sequences loaded from an external supervisory processor. Less flexible surface acoustic wave (SAW) matched filters have become available which are suitable for both generating and demodulating DSSS signals.

The initial STA was approved by the FCC for our group's use in April, 1992, and was extended in May, 1993. Each STA authorized operation for a one year period.

STA Objectives

Specific objectives of the STA are to:

(1) assess the strengths and weaknesses of the proposed systems;
(2) evaluate the potential of spread spectrum overlay on conventional FM systems;
(3) determine interference impact, if any, to existing users;
(4) evaluate immunity to intersymbol interference due to multipath propagation;
(5) evaluate potential for improved spectrum utilization;
(6) evaluate performance improvement claimed for CDMA; and,
(7) gain operational experience.

STA Experiments

Several systems have been and/or are being evaluated under this STA:

A direct sequence system based on custom ASIC digital baseband components was exercised for several months each on 420 MHz, 915 MHz, and 2440 MHz. The digital modulation was generated by 2 data bits selecting one of 4 unique symbols, each represented by an orthogonal 32-bit spreading sequence. The binary stream was bandwidth shaped and fed to a BPSK modulator. Reception was accomplished by demodulating the BPSK signal into I and Q baseband channels, driving 4 parallel correlators which deliver 2 bits of decoded data. This is a "despread after demodulation" system. It performed well at high data speeds in environments where there was little channel interference. At mountaintop repeater locations populated with many high power, narrowband emitters, the performance was predictably poor. Half megabit data rates over 30-50 mile paths were intermittently achieved from these locations. Reducing the data rate to 50 Kbps (1.6 MHz occupied channel width) and frequency hopping the channel center produced channel reliability near 90%. Because this system operates on arbitrarily-chosen spreading sequences, we constructed two identical systems and tested them asynchronously in the same spectrum using low cross-correlation spreading codes. No performance degradation could be observed on one system while the other was operating. This demonstrated the popular property called Code Division Multiple Access (CDMA). With the sequences we were testing, we estimated that upwards of 100 systems could operate simultaneously without interference (meaning that we were able to identify 400+ "mutually orthogonal" spreading sequences), though this number is reduced by inband narrowband emitters. Each transmission went through a synchronization phase, where the receiver trained on a 32-bit unique word header. This insured that no time synchronization was required between (possible) multiple participants in one network (those stations using one of the sets of spreading codes). Throughout this exercise, we imposed as a minimum criteria that required by 15.247.

We wanted to study the hard problem of sharing spectrum with existing (narrowband FM repeater) systems. The spectrum we chose is that occupied by the 2 meter repeater transmitters which heavily populate Southern California. Here the signal spectral density is very high. With considerable effort, we built several conventional frequency-synthesized transceivers capable of changing frequency on 25 KHz channel centers in 500 microseconds. This provides a total of 160 channels within the band, but for much of the experimentation we limited transmission to the 50 channels located on or near repeater outputs. Receivers used IF filters of 30 KHz width, permitting 12 KBps GMSK data rate. Channel hopping order was computed using the algorithm presented 20 years ago by Gustave Solomon in his paper "Optimal Frequency Hopping Sequences For Multiple Access," in the Proceedings of the 1973 Symposium on Spread Spectrum Communications. [Appendix-1] These sequences are a special case of Reed-Solomon codes, which appeared in the early 1960's. Continuous transmissions limited to 5 milliseconds per channel went completely unnoticed while suffering collision rates between approximately 40% at busy times of the day to less than 5% otherwise. The choice of data speed and modulation type was fortuitous, sounding much like the usual signal fading normally experienced with mobile repeater users. Avoiding user panic when trying new ideas goes a long way toward gaining acceptance. Extrapolating the data we collected and taking advantage of system improvements we now think are possible, 15 to 20 simultaneous systems could operate with little impact either to each other or to existing voice users. Of course, this system will not survive the hostilities of nearby transmitters. This is the traditional problem for Spread Spectrum, often called "near-far."

An experiment we are just beginning uses a combination of direct sequence and frequency hopping on 6 meters. Two recent developments have contributed to this project: (a) the availability of inexpensive Numerically Controlled Oscillators (also called Direct Digital Synthesizers), and (b) the license to use the patented OQPSK modulation technology due to Dr. Kamilo Feher of University of California at Davis. OQPSK is spectrally efficient, giving between 0.7-1.2 bits/hertz, and it can be amplified by nonlinear amplifiers. Signal generation lends itself to NCO methods. Coherent demodulation is required, significantly complicating the receiver. Using short spreading sequences to counteract multipath intersymbol interference and frequency hopping to avoid wideband noise sources, we hope to achieve reliable high-speed non-line-of-sight communication over 50-150 mile paths.

Related Efforts

Work is progressing in the context of IEEE 802.11 to define a standard for short range, interoperable spread spectrum data communications devices operating under Part 15 Rules. The major emphasis thus far has been placed on slow frequency hopping protocols using conventional FM-GFSK modulation. A direct sequence protocol is less mature, based roughly on the work of NCR/Wavelan using DQPSK modulation spread by an 11-bit Barker code. Spreading gains have been chosen at the FCC-required minimum 10 dB value in order to meet the IEEE 802 minimum data rate of 1MB/s in the channel widths allowed by the FCC. Two contributed papers are included here, both from IBM: "Selection Criteria for Frequency Hopping Pattern Set," IEEE 802.11/92-84 [Appendix-2], and "Frequency Hopping Pattern Selection," IEEE 802.11/93-60 [Appendix-3]. It is interesting to note that the mathematics draws on the work of Solomon [1], though Dr. Le Maud did not realize it at the time. These papers are a very nice technical assessment of the interference-limited situation our radio service faces, and they also show the importance of having available the freedom to chose the technology appropriate to the problem.

STA Observations

(1) So, why isn't there more SS experimentation? Spread Spectrum is not ordinary, so the challenge should attract the wild-at-heart. Successful SS realizations provide robust, interference-resistant links, and these results are satisfying indeed to achieve. Building and testing SS systems requires a variety of special talents. It is hard work, it is very time consuming, and the cost of component parts is unusually high. But the real reason has to do with the fact that with the current limitations on the mode, there is no payoff. The likely beneficiary of successful SS efforts is the digital community: packet radio, and digital voice.

(2) Could more be done within the current limitations? Yes, but the cost is considerable. Phil Karn correctly points out that, if all participants in a network have available a very accurate source of time, Multiple Access can be achieved using time-slip phasing of the same m-sequence spreading code. If we could accurately time-synchronize the transmissions of all the frequency-hoppers operating in our common coverage area, we avoid mutual interference accordingly. In an environment with many "hidden-terminals," the cost of accurately distributing "time" can be astronomical. Cost is an important factor in Amateur Radio.

(3) There is the ever-present "near-far" problem. Trying to get a wideband receiver to work well near a high power transmitter has always been tough, though not impossible. Again, the tradeoff is cost. More work is needed to find good cost-effective solutions to this problem.

(4) Designing a transmitter which is inherently wide, yet has an identification mode that can be detected by narrowband receivers is an oxymoron. Just the same, it is important. It keeps us honest, and it helps to resolve interference issues and responsibilities. Often, turning off the spreader is not enough. We did find that unbalancing a DBM at a MORSE-CW rate was effective.

Rule-change Proposal

(1) Allow the use of any spreading function.
(2) Allow SS emissions on all VHF and higher bands (50 MHz and up)
(3) Allow "hybrid" systems consisting of combinations of SS generators.
(4) Standardize the transmitter Identification message (callsign/SS)
(5) Require registration of SS systems (e.g.: public databases on ARRL/Internet BBSs)
(6) Extend the STA indefinitely, or until the rules are changed. (Eliminate paperwork)

Third Response

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554
December 27, 1994

Mr. Robert Buaas
20271 Bancroft Circle
Huntington Beach, California 92646

Dear Mr. Buaas:

This is in response to your request dated April 30, 1994, for extension of the special temporary authority (STA) and waiver of the Commission's rules that were granted on May 26, 1993. That STA and waiver permitted certain amateur stations to conduct experiments involving Code Division Multiple Access (CDMA) spread spectrum (SS) emissions.

Your request was presented to the Interagency Radio Advisory Committee, which expressed no objection to an extension. Accordingly, the STA and waivers granted May 26, 1993, are extended until completion of your data communication experiments. All other conditions of the May 26, 1993, authorization will remain in effect.

Sincerely,

/S/ Robert H. McNamara
Acting Chief, Private Radio Bureau

