Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of Part 97 of the Commission's Rules	)	
to Facilitate Use in the Amateur Radio Service of	)	RM-11625
Single Slot Time Division Multiple Access	)	
Telephony and Data Emissions	)	

COMMENT OF THE CODEC2 PROJECT

December 23, 2012

To the Commission:

1. INTRODUCTION

1. This comment is in regard to RM-11625 only. No opinion is represented regarding other rule-making in this docket.

2. This comment is our response to the request in paragraph 28 of the NPRM: *We also seek comment on whether any other specific emission types should be permitted.* Our *short* answer would be *yes, all of them, and please leave it to Radio Amateurs to further coordinate which goes where.*

3. The Codec2 Project supports allowance of the Motorola-derived TDMA system which is the purpose of ARRL's Petition for Rule-making in this matter.

4. However, we believe that the proposed rule-making is unnecessarily inflexible. It continues a regulatory framework that has diverged from the technology and the needs of the Amateur Radio service. We urge FCC instead to apply a framework that recognizes the reality of communication today: one based solely on emitted bandwidth, rather than increasingly-blurry, and unnecessarily restrictive, definitions of emission "type."

5. We present a digital system capable of encoding voice in a 1.1 kHz bandwidth signal, intended mainly for use in Amateur spectrum between 1 and 30 MHz, but also usable above 30 MHz. We request appropriate regulatory changes to authorize this mode.

6. We seek a clarification of 47 CFR 97.309(b) regarding whether an unspecified digital voice codec should be considered an unspecified digital code. The Motorola-derived TDMA system that is the subject of this rule-making incorporates an unspecified digital voice codec.

7. This is also a comment as requested by FCC under the Paperwork Reduction Act of 1995, Public Law 104-13. It suggests a rule change that would result in a subsequent paperwork reduction.

8. There are three exhibits attached to this comment:

- Exhibit **1**: This exhibit may be downloaded from http://files.freedv.org/FCC/Codec2_RM11625_Exhibit_1.zip because the ECFS is not able to store zip archives. This is the complete source code of Codec2 and an associated soft-modem and application program, to demonstrate that a *fully-specified* digital voice codec of acceptable performance is now available for use in Amateur Radio communications.

  It is *not* necessary for anyone at FCC to read or print this source code as part of the

NPRM process. We have included it as evidence for any interested party to download and examine at their convenience.

- Exhibit **2**: This exhibit may be viewed at http://freedv.org/tiki-index.php?page=video because the ECFS is not able to store videos. This is a video demonstrating use of Codec2 with a software-defined Amateur Radio transceiver, in an HF digital voice communication of over 900 miles distance.
- Exhibit **3**: Executable programs for using Codec2. To avoid concerns over viruses, etc., we are hosting these at our own web site rather than FCC's ECFS system, which was not designed to redistribute executable software. Any party wishing to test this software can access it at http://freedv.com/downloads/

2. DISCUSSION

A. Introduction to the Codec2 Project

9. The Codec2 Project is an unincorporated international Open Source project to produce a low-bandwidth digital voice codec for use in Amateur Radio communication. *Open Source* means that our codec is fully disclosed, and without significant intellectual property restrictions. This is important because of the educational and innovation missions of Amateur Radio: if they are to be educated, Radio Amateurs must be allowed the necessary information to *understand* their technology fully. To innovate, they must be able to *produce* it themselves, *experiment* with it, and *improve* it. The technology of other codecs used on Amateur Radio is secret, and this creates a barrier to innovation and education.

B. Technical Development of the Codec2 Project

10. To introduce our demonstration of how the regulatory needs of our project differ from those in the proposed rule-making, here is a short explanation of the products created by the Codec2 project:

> Codec2: An ultra-low-bandwidth codec for communication of telephone-quality speech at only 1200 Baud, and with increased quality at rates up to 3200 Baud, implemented entirely in software and requiring no more computational power than common mobile CPUs.
>
> FDMDV: A multi-carrier software modem for use primarily on the Amateur bands below 30 MHz. In combination with Codec2, it achieves clear digital voice communications in 1.1 KHz of bandwidth, less than 1/2 of the usual bandwidth of an SSB transmission.
>
> FreeDV: An application program for multiple operating system platforms which incorporates Codec2 and FDMDV2. It provides digital voice communications by driving an SSB transceiver to transmit and receive a digital voice signal.
>
> C2GMSK: A GMSK software modem for use primarily on the Amateur bands above 30 MHz. In combination with Codec2, it provides digital voice communications using existing Amateur transceivers that were built for FM modulation.

11. FreeDV (incorporating Codec2 and FDMDV) is in beta testing, with daily use by interested Amateurs. The testers carry out an online discussion at http://groups.google.com/group/digitalvoice

12. C2GMSK is in early development.

13. These products are not encumbered by patents and are free for anyone to use, copy, redistribute, and modify. They can be incorporated into commercial products using the license attached to them, without any need to contact the Codec2 Project or negotiate a contract. There is no royalty or fee.

C. The Importance of Open Source To This Discussion

14. Because we use software-defined radio, the Codec2 Project is able to implement a new modulation scheme with a different modulation designator from our previous work by changing a few lines of software. A knowledgeable programmer could easily perform and test this work in an hour. We

can deploy that software to the entire Amateur community in minutes using the Internet or Amateur Radio digital communications. We have already implemented automatic notification to the end user of new software versions. Users can be expected to download new versions as they are released, and thus remain compatible with other users as new features reach the air.

15. Because our project is Open Source, our developer community is not limited to a single company. All who wish to participate may join the development team. Developers are around the globe, with recent contributions from Australia, Sweden, Norway, Russia, Canada, and the United States. There is significant interest in our codec from industry and thus several developers have commercial funding to work on Codec2, while others are self-funded volunteers.

16. This rapid development and rapid update capability, along with the broad development community, fosters a continuous-innovation process, in which Amateurs experiment and modify the Open Source software, and their improvements are rapidly propagated to the entire Amateur community.

17. Given the history of the more popular Open Source products, we expect to maintain from 20 to 100 active developers on this project alone as it progresses. There are, and will be, other Open Source projects creating new modulation modes as well.

18. The point is that development is already rapid, and will only increase. The current regulatory framework will not keep up with this development.

19. Because we are Open Source, regulators have immediate access to our products' source code and therefore to the underlying algorithms and encoding systems used. Day to day changes in software are recorded in a public revision control system, and can be accessed by any interested person via the internet at http://freetel.svn.sourceforge.net/viewvc/freetel/

20. Although specification of an algorithm can also be made in a human-readable document, such specifications often diverge from the actual software, especially in a project that is still under active development. Only source code shows what the software *actually* does.

D. The Regulatory Framework Continued By This NPRM Would Not Handle Software-Defined Radio Well

21. ARRL's petition seeks approval of a single implementation of digital communications, originating with one company: Motorola. This system is mainly available in products from Motorola and Yaesu (which was formerly or is presently owned by Motorola).

22. The Motorola-derived TDMA system is sold mainly as a physical device that is constrained to use Motorola's specific modulation. Even if the Motorola device contains an embedded processor and firmware and uses software-defined radio techniques internally, users are locked out of modifying its firmware by both the physical design and intellectual property restrictions. This contrasts starkly with Amateur Radio's mission to advance the state of the art.

23. Amateurs are encouraged to modify and extend the Codec2 Project's software modems, and can thus make them produce any modulation type whatsoever and advance the radio art without encumbrance.

24. The requirement that FCC must approve each significantly different modulation type to reach Amateur Radio, as is followed in the NPRM, is appropriate for a manufacturer-locked system like that from Motorola, or for a hardware-only radio implementation, because such devices can only be expected to use a fixed set of modulation types. However, should FCC continue this process of authorizing one or two modulation types at a time, it will fall further and further behind new Amateur developments taking advantage of software-defined radio. Continuation of this piecemeal process of authorization would place severe regulatory hurdles before the Codec2 Project and hinder the capability of Radio Amateurs to experiment and innovate.

25. We include the *current* specification of the modulation of our FreeDV program, including a

modulation designator, in Appendix B. Because this program includes a software modem and software codec, further development of the program is expected to obsolete this specification. Even the modulation designator may not remain the same as it is today.

E. The NPRM Proposes a Legal and Technical Fiction

26. The regulatory framework continued by the proposed rule-making was initiated when radiotelephone became a popular mode in the Amateur service. Its original purpose was to grant Morse code operators protection from interference by the new voice users. This usage still shows in the NPRM. In an attempt to shoehorn digital communications into existing rules that separate voice and telegraphy bands, the NPRM proposes a fiction that "digital voice" is in some way different from "digital data".

27. This fiction is followed in the use of two separate modulation designators "FXE" and "FXD" for what is actually the same modulation, transmitted by the same system, with only a difference in the *momentary* use of the data payload. For a digital communication over radio, the last symbol of the modulation designator should always be "D" regardless of the content. Even the "voice" transmissions in the Motorola-derived product include significant textual content containing call-signs, data routing, authentication, call prioritization, geolocation, and other information, as is the case for most Amateur digital "voice" communications.

28. The new Yaesu FT-1D, their first model incorporating the Motorola-derived TDMA system, offers a camera in an optional external microphone. However, the NPRM does not attempt to accommodate this camera by authorizing "FXF" (television) or "FXC" (facsimile) as yet another separate mode. The FT-1D also contains a GPS for geo-location similar to that used by the APRS and D-STAR systems. Modern digital systems can be expected to incorporate any conceivable combination of voice, textual, image, geo-location, telemetry, and other information within the data payload of a single transmission.

29. In the analog radio age, the type of communication accommodated by a system was necessarily much more fixed than it is today. Radios, televisions, teletypes, and telegraphs were separate physical objects, and it was appropriate to use a single modulation designator letter to express the continuous program content being carried by those devices. Of course a single computer can encompass the function of all of those devices today. To attempt to express the rich data set carried along with digital voice as an "E" on the end of a modulation designator simply ignores the versatility of computer communications. The time when modulation designators could reflect the continuous content of a communication is past. Amateur regulations should reflect that fact.

F. Digital Communications Turns FCC's Amateur Band-Planning On Its Head

30. A main thrust of the FCC-enforced Amateur band-plan has been to protect narrow-band modes, primarily radiotelegraphy (defined as a *digital* mode), from interference by wide-band modes, primarily voice communications. Voice is allowed in limited sub-bands, while telegraphers can operate in both the exclusively digital (meaning telegraphy) sub-bands *and* the voice bands.

31. Digital communications turns this upside down, because the proposed "voice" modulations are limited to be used in voice band segments, while the proposed "digital" modulations, which can carry many different kinds of information, are admitted to band-segments that were previously the protected domain of telegraphy.

32. While FCC could extend the band plan to separately authorize digital-television, digital-voice, digital-text, etc., the reality is that a single digital communication should be expected to carry many of these modes simultaneously. Regulating the type of payload just doesn't make sense. Should we not encourage the use of modes that transmit more information in a narrower bandwidth, conserving the spectral resource? Regulating the bandwidth of the digital communication could work to minimize interference and maximize innovation.

G. Why Do We Have The Current Regulatory Framework, Anyway?

33. The micromanagement of Amateur modulation modes and sub-bands by FCC arose from the desires of Radio Amateurs rather than any need of the United States Government. In the past, FCC operated many field offices, devoted significant human resources to Amateur enforcement, and proctored Amateur license examinations in its offices using its own staff. It might have made sense *then* for FCC to manage the Amateur band-plan and to enforce it with Federal officers, and FCC was persuaded to enact a set of regulations that protected radiotelegraphy from radiotelephone interference. Later, Federal management of the band-plan was extended to implement a privilege hierarchy for incentive licensing of Radio Amateurs, in which higher grades of licensee were granted increased privileges over lower grades. This left FCC in the position of having to enforce the Amateur band-plan in order to maintain incentive licensing.

34. Today, FCC can not, does not, and in fact does not need to devote significant resources to managing a band-plan for Radio Amateurs. This is demonstrated by the fact that FCC did not announce any objection to what ARRL claims as "numerous" present installations of the Motorola-derived TDMA system until ARRL brought the matter to FCC's attention in a Request for Waiver. FCC has entirely offloaded Amateur testing to volunteers, except for rarely ordered re-examinations in connection with enforcement. Special licensing of repeaters is no longer carried out, and FCC has offloaded repeater frequency coordination to Amateurs. For much of the past decade the entirety of Amateur enforcement and coordination with other services appears to have been operated by one attorney. Thus, it is unlikely that FCC can continue to support the administrative load of approving new modulation types piecemeal as they are proposed.

35. The United States is unusual in having its telecommunications regulator enforce an Amateur Radio band-plan. Most nations implement these as policies of a national Amateur Radio society, which takes the lead in maintaining them. The United Kingdom telecommunications regulator *Ofcom,* for example, leaves Amateur band-planning for England, Wales, Northern Ireland, and Scotland to the Radio Society of Great Britain. That Amateur Radio society implements the band plan agreed to by the International Amateur Radio Union (IARU) with a small number of local changes. IARU arrives at its band plan by agreement of the world's national Amateur Radio societies. IARU is administered by ARRL as its perpetually re-elected International Secretariat. Thus, ARRL is already active in producing the Amateur Radio band plan that is observed by many nations other than the United States.

H. A Modern Band-Plan for United States Amateur Radio.

36. A modern band-plan implementation for US Amateur Radio would have FCC mandating only the minimum necessary specifications: those required by international treaties, and those necessary to prevent Amateurs from interfering with other services.

37. The rest would come from a group similar to the one that operates the volunteer-examiner question pool today. In such a plan FCC might specify the band segments open to various license classes, and requirements for power and spurious emissions, and allow the volunteer organization to specify the rest.

38. Of course, there's the question of how much power such an organization should have to enforce the band plan. Many nations treat Amateur band-plans as simply the mutual agreement of all polite Amateurs. While this might be sufficient, FCC might grant to band planning organizations as much regulatory weight as it presently gives to private repeater frequency coordinating bodies.

39. A modern band-plan would not specify modulation designators at all. An alternative to specifying modulation designators is to specify bandwidth. As evidence of such a plan, we have included in Appendix A an HF bandwidth-based band plan produced by Bonnie Crystal KQ6XA in 2004. However, FCC does not *have* to specify the bandwidth of Amateur communications in Part 97 other than relating to out-of-band emissions. It can offload this task to the Radio Amateurs themselves along with the rest of Amateur band-planning.

40. Many other nations, including **Canada**, today implement bandwidth-based planning for the Amateur bands. Thus, we in the U.S. share our entire Amateur spectrum with a bandwidth-based regulatory regime that is within communications range of all U.S. HF users and many VHF and UHF ones. We are not aware of interference to U.S. Amateurs arising from Canada's bandwidth-based regulation. Thus, it is unlikely that U.S. Amateur Radio would be damaged by similar regulation.

41. Industry Canada's bandwidth-based Amateur Radio regulation is available on the web at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01226.html#sche1

I. 97.309 Data Transmission Codes

42. 47 CFR 97.309 (1) through (4) list authorized data transmission codes, all of which are obsolete in current computer usage. ASCII is being replaced by UNICODE, and the 5-level Baudot code is an antique with little remaining use outside of Amateur Radio.

43. All of the stated codes are textual, and are thus inapplicable to non-textual data such as the binary representation of numeric data, images, and digital voice encoding.

44. As documented in Appendix B, our FreeDV program uses a varicode text character set which is a compression of ASCII into fewer bits, and is thus not any of the presently authorized transmission codes. This character set is publicly disclosed.

45. We suggest that FCC allow any digital code that is publicly disclosed such that a knowledgeable person can construct a computer program to encode and decode it.

J. 97.309(b) and Undisclosed Digital Voice Codecs

46. 47 CFR 97.309(b) begins: *a station may transmit a RTTY or data emission using an unspecified digital code, except to a station in a country with which the United States does not have an agreement permitting the code to be used.*

47. We suspect that this regulation could exist to implement an international treaty requirement, perhaps one regarding espionage, but we are unaware of such a treaty. This regulation also supports the military, intelligence, and law-enforcement requirements of the United States Government.

48. We believe that transmissions that can not be decoded by the general public have no place in Amateur Radio, except in the very limited capacity authorized for remote control of devices in outer space. To preserve the *shared* nature of Amateur Radio, the means to monitor any and all Amateur communications should be available to all interested person. Obviously, an undisclosed digital code would prevent such monitoring by any individual who is not party to private information regarding the code.

49. Undisclosed digital voice codec products, such as that used in the Motorola-derived system, are undisclosed digital codes. The mathematical algorithm they use to encode and decode voice is secret, and consequently the information necessary to decode the bit-stream produced by them is secret. To an observer the effect is the same as that of an undisclosed digital code used for textual, graphical, or other non-voice information – an un-decodable message.

50. The type of digital voice codec used in the Motorola-derived TDMA system is a special case. While its algorithm and bit-stream contents are undisclosed, it is available for the public to purchase in “black box” form: an integrated circuit chip which can translate between the encoded bit-stream and digital audio in the clear. This chip contains the secret codec algorithm in a form that can not be read from the device, but on demand it will execute the algorithm on user-provided data.

51. Thus, the general public can decode digital audio from this particular codec, but only by purchasing a device that contains the codec chip, such as a radio built specifically for the Motorola-derived TDMA system. There is no known way to decode the transmission without the chip. Reverse-engineering is prohibited by contractual requirements upon the purchaser and laws regarding intellectual property and trade secrets.

52. This creates a monopoly, because the only means of inter-operating with an undisclosed digital voice codec is to purchase a component made by or licensed by a single company.

53. The undisclosed digital voice codec in the Motorola-derived system is called AMBE, and is produced by Digital Voice Systems Incorporated (DVSI). AMBE is also the voice codec of the D-STAR system, in common use by radio amateurs. To decode AMBE under computer control, a company has produced the *DV-Dongle.* This incorporates the AMBE chip from DVSI and can execute the secret codec algorithm when commanded to through a USB interface.

54. However, DV-Dongle is prohibitively expensive for its function and computational power. It performs in a $200 proprietary USB device a function analogous to what Codec2 does in free software that runs on the same computer without requiring any plug-in accessory. This extra $200 cost is attributable exclusively to hiding the secret algorithm, which could otherwise be placed in software and run on the main CPU.

55. A DVSI chip, either AMBE or an earlier one called IMBE, is also used in the APCO Project 25 systems. The Federal Government provides state and local organizations with funds for radio communication systems, with the *requirement* that these systems implement the APCO Project 25 specification. Thus, it appears that the Federal government does not have prohibitive issues with DVSI's undisclosed digital codecs.

56. However, it is important to note that a significant monopoly exists. APCO Project 25 and D-STAR manufacturers and users must necessarily purchase from DVSI, or from a company that itself purchases from or is licensed by DVSI, if they are to inter-operate with APCO Project 25 or D-STAR systems. There can be no other sources for such a chip without a license from DVSI. While a black-box chip purchase for integration in a manufactured device is under $20 per unit, licensing the technology is said to cost more than one million dollars.

57. Other nations may be loath to accept a requirement to purchase or license secret technology from DVSI, a U.S. company, in order to monitor communications in their own territory.

58. Are other nations actually concerned by Amateur transmissions using undisclosed digital voice codecs? Yes. In April 2010, the French communication regulator *ARCEP* denied Amateurs authorization to use D-STAR or F7W modulation. The document (in French) is at http://draf.asso.fr/public/Dstar/Reponse_ARCEP_120410.pdf

59. English-language web commentaries by French amateurs render several reasons for ARCEP's decision: use of the undisclosed code could cause a national security risk, the system could be used to access the Internet, and the monopolistic proprietary nature of the codec is incompatible with the non-pecuniary definition of the Amateur service.

60. In furtherance of international relations, we believe that 47 CFR 97.309(b) should be applied to voice transmissions using undisclosed digital voice codecs as it would be to any other kind of data encoded in an undisclosed digital code.

K. Undisclosed Digital Voice Codecs and the Purpose of Amateur Radio

61. Education and innovation are two primary purposes of Amateur Radio. For a century Radio Amateurs have been able to build every part of their systems, if they wished. There has been no part of the technology of Amateur radio that Radio Amateurs were not *allowed* to understand. In fact, the technical questions on the FCC-mandated Amateur license exams *required* such understanding before an Amateur could be licensed. Hams published their schematics for all comers to use and learn from, and successful "home-brewers" who constructed their own equipment and used it on the air were held in esteem by other Amateurs. The tinkering that these people did to improve their home equipment drove much of the innovation of the radio age.

62. This era when hams were allowed to understand all of the technology of Amateur Radio **ended** with the introduction of undisclosed digital voice codecs to Amateur radio. Specifically, the D-

STAR system introduced the undisclosed AMBE codec to common use in Amateur Radio. Contractual requirements upon the purchaser and intellectual property law prevent hams from acquiring knowledge of AMBE or duplicating it in software. Amateurs using these systems are forced to become, to some extent, "appliance operators" who are not allowed, much less able, to understand their radios.

63. By producing an Open Source low-bandwidth digital voice codec, The Codec2 Project has *restored* the capability of Amateurs to innovate with *all* of their technology. Our codec is already being adopted for use in many purposes outside of Amateur Radio, and is introducing many programmers to the internals of voice coding technology. Thus, we continue the missions of Amateur radio.

64. Any black-box technology would be harmful to the purpose and spirit of Amateur Radio. The broad achievements of Open Source developers across the entire field of computing have shown that there is no technical reason for black-box technology.

65. Over time, we expect to drive undisclosed digital voice codecs from Amateur radio via free market competition and superior technology. We do not feel that we need any help from regulators to remove this problem from the Amateur airwaves.

L. Paperwork Reduction

66. FCC is responsible to implement the Paperwork Reduction Act of 1995, Public Law 104-13. ARRL's Request for Rule-Making is to authorize two additional modulation types. Subsequent to our suggested changes, all digital modulation types would be authorized and no further requests of that type would be necessary. Thus, our suggested changes would cause a paperwork reduction.

3. CONCLUSION

67. We propose three sets of regulatory changes, which we have labeled *Small, Medium,* and *Large*. The *Small* set specifies an exhaustive set of modulation designators for approval. This can be applied to the current rule-making with minimal changes. Thus, FCC can facilitate software-defined radio without unduly extending the rule-making process. The *Medium* set moves the regulatory framework of Amateur Radio further into the present by switching to a bandwidth-based regulatory regime rather than a modulation-designator based one. The *Large* set offloads Amateur Radio band-planning to Radio Amateurs, *including* the designation of allowable bandwidth for communications in various sub-bands.

68. We urge that FCC not table this issue until it eventually implements the *Large* set, but we will leave the timing of that implementation to FCC for now. We urge that at a minimum, the *Small* set should be implemented in the current rule-making, and the rule-making should be carried out without delay.

A. "Small" Version of Regulatory Changes

69. The intent of these suggested changes is to authorize digital communications using specified codes and arbitrary modulation with bandwidth similar to that previously authorized or that of other band users, wherever possible within the Amateur spectrum.

70. Amend Section 97.3(2) to read:

> (2) Data. Any communication encoded as digital information; Regardless of content, any transmitted information encoded in digital form shall be considered to have D as the third emission designator symbol. Emissions having (i) designators with A through X excluding N as the first symbol, 1 through 9 or X as the second symbol, and D as the third symbol; (ii) emission J2D; and (iii) emissions A1C, F1C, F2C, J2C, and J3C having an occupied bandwidth of 500 Hz or less when transmitted on an amateur service frequency below 30 MHz.

71. Amend Section 97.305 to add authorization of standard (3) in all spectrum where standard (1) and (2) are presently authorized. This thus authorizes digital modes that carry radiotelephone and other data in spectrum where radiotelephone and data are presently authorized.

72. Section 97.307(3) presently reads:

> (3) Only a RTTY or data emission using a specified digital code listed in §97.309(a) of this part may be transmitted. The symbol rate must not exceed 300 bauds, or for frequency-shift keying, the frequency shift between mark and space must not exceed 1 kHz.

73. To determine the equivalent bandwidth for the specified symbol rate of 300 and the shift rate of 1000 Khz, assuming one bit per symbol, we use $bandwidth = 1.2\Delta f + b$ where f is the shift rate, b the symbol rate, and *1.2* an assumption to account for the distortion of the signal path. We arrive at 1.5 kHz.

74. Thus, Amend Section 97.307(3) to read:

> (3) A RTTY or data emission using a digital code as authorized in 97.309(a) may be transmitted. The authorized bandwidth is 1.5 kHz.

75. Amend section 97.307(8) to read:

> (8) A RTTY or data emission using a digital code as authorized in 97.309(a) or (b) is also authorized.

76. Amend Section 97.309(a) to read:

> Any digital code that is fully disclosed to the public in sufficient detail that a knowledgeable person can create a computer program to encode and decode it, or any digital code of a type specifically authorized in this part, may be transmitted.

77. Strike Section 97.309 (1) through (4), as the change above makes them redundant.

B. "Medium" Version of Regulatory Changes

78. The intent of these suggested changes is to implement bandwidth-based regulation based upon that of Canada, while preserving band-segments that are limited to narrow-band operation in the U.S. at their presently-authorized bandwidths. Incidentally, some harmonization with Canadian Amateur spectrum regulation is achieved.

79. Amend Section 97.305(c), replacing it with the following:

Stations in the Amateur service are authorized to tramsit all types of emission except for unmodulated carrier, of no greater than the maximum bandwidth set out the following table. The bandwidth of a signal shall be determined by measuring the frequency band occupied by that signal at a level that is 26 dB below the maximum amplitude of that signal. Where the bandwidth is indicated as "Not specified", the bandwidth must be the minimum necessary to carry the desired emission.

Wavelength Band	Frequencies	Bandwidth Authorized	Additional Authorizations and Restrictions, Sharing Requirements
160 m	Entire band	6 kHz	Amateur stations transmitting in the 1900–2000 kHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government, the FCC, or other nations in the radiolocation service. Amateur stations transmitting in the 1900–2000 kHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the fixed, mobile except aeronautical mobile, and radionavigation services.

80 m	3.5 – 3.6 MHz	1.5 kHz	A station having a control operator holding a Novice or Technician Class operator license may only transmit a CW emission using the international Morse code.
80 m	3.6 – 4 MHz	6 kHz	
60 m	Entire band	2.8 kHz	Channelized operation only, channels are 5330.5, 5346.5, 5357.0, 5371.5, 5403.5 kHz. Only USB single-sideband voice with 2.8 kHz maximum bandwidth or CW centered 1.5 kHz above the lower channel boundary.
40 m	7.0 – 7.125 MHz	1.5 kHz (with a 6 kHz band segment in certain regions).	A station having a control operator holding a Novice or Technician Class operator license may only transmit a CW emission using the international Morse code and only between the frequencies of 7.0 – 7.1 MHz. Up to 6 kHz bandwidth may be used only by stations located in ITU Regions 1 and 3, and by stations located within ITU Region 2 that are west of 130° West longitude or south of 20° North latitude.
40 m	7.125 – 7.3 MHz	6 kHz	Amateur stations transmitting in the 7.2–7.3 MHz segment must not cause harmful interference to, and must accept interference from, international broadcast stations whose programming is intended for use within Region 1 or Region 3.
30 m	Entire band	1.5 kHz	Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the fixed service. The licensee of the amateur station must make all necessary adjustments, including termination of transmissions, if harmful interference is caused.
20 m	14.0 – 14.15 MHz	1.5 kHz	
20 m	1.150 – 14.35 MHz	6 kHz	
17 m	18.068 – 18.11 MHz	1.5 kHz	
17 m	18.110 – 18.168 MHz	6 kHz	
15 m	21.0 – 21.2 MHz	1.5 kHz	A station having a control operator holding a Novice or Technician Class operator license may only transmit a CW emission using the international Morse code.
15 m	21.2 – 21.45 MHz	6 kHz	
12 m	24.89 – 24.93 MHz	1.5 kHz	
12 m	24.93 – 24.99 MHz	6 kHz	
10 m	28.0 – 28.3 MHz	1.5 kHz	
10 m	28.3 – 29.7 MHz	20 kHz	A station having a control operator holding a Novice Class operator license or a Technician Class operator

			license and who has received credit for proficiency in telegraphy in accordance with the international requirements may only transmit a CW emission using the international Morse code or phone emissions J3E and R3E between 28.3 and 28.5 MHz.
6 m	50.0 – 50.1 MHz	500 Hz	
6 m	50.1 – 54.0 MHz	30 kHz	
2 m	144 – 144.1 MHz	500 Hz	For amateur stations located in ITU Regions 1 and 3: Amateur stations transmitting in the 146–148 MHz segment must not cause harmful interference to, and must accept interference from, stations of other nations in the fixed and mobile services.
	144.1 – 148 MHz	30 kHz	
1.25 m	219 – 220 MHz	100 kHz	Use is restricted to amateur stations participating as forwarding stations in fixed point-to-point digital message forwarding systems, including intercity packet backbone networks. It is not available for other purposes. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by: the FCC in the Automated Maritime Telecommunications System (AMTS), the 218–219 MHz Service, and the 220 MHz Service, and television stations broadcasting on channels 11 and 13; and other nations in the fixed and maritime mobile services. No amateur station may transmit unless the licensee has given written notification of the station's specific geographic location for such transmissions in order to be incorporated into a database that has been made available to the public. The notification must be given at least 30 days prior to making such transmissions. The notification must be given to: The American Radio Relay League, Inc., 225 Main Street, Newington, CT 06111–1494. No amateur station may transmit from a location that is within 640 km of an AMTS coast station that operates in the 217–218 MHz and 219–220 MHz bands unless the amateur station licensee has given written notification of the station's specific geographic location for such transmissions to the AMTS licensee. The notification must be given at least 30 days prior to making such transmissions. The location of AMTS coast stations using the 217–218/219–220 MHz channels may be obtained from The American Radio Relay League at the address noted above.

1.25 m	222 – 225 MHz	100 kHz	
70 cm	Entire band	12 MHz	No amateur station shall transmit from north of Line A in the 420–430 MHz segment. See §97.3(a) for the definition of Line A. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government in the radiolocation service. Amateur stations transmitting in the 430-450 MHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the radiolocation service. Amateur stations transmitting in the 420–430 MHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the FCC in the land mobile service within 80.5 km of Buffalo, Cleveland, and Detroit. See §2.106, footnote US230 for specific frequencies and coordinates. Amateur stations transmitting in the 420–430 MHz segment or the 440–450 MHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the fixed and mobile except aeronautical mobile services.
33 cm	Entire band	12 MHz	No amateur station shall transmit from those portions of Texas and New Mexico that are bounded by latitudes 31°41' and 34°30' North and longitudes 104°11' and 107°30' West; or from outside of the United States and its Region 2 insular areas. No amateur station shall transmit from those portions of Colorado and Wyoming that are bounded by latitudes 39° and 42° North and longitudes 103° and 108° West in the following segments: 902.4–902.6 MHz, 904.3–904.7 MHz, 925.3–925.7 MHz, and 927.3– 927.7 MHz. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by: The United States Government; The FCC in the Location and Monitoring Service; and ; Other nations in the fixed service. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government

			in the radiolocation service. Amateur stations must accept interference from industrial, scientific, and medical (ISM) equipment.
23 cm	Entire band	Not specified.	Amateur stations transmitting in the 23 cm band must not cause harmful interference to, and must accept interference from, stations authorized by: The United States Government in the aeronautical radionavigation, Earth exploration-satellite (active), or space research (active) services; The FCC in the aeronautical radionavigation service; and Other nations in the Earth exploration-satellite (active), radionavigation-satellite (space-to-Earth) (space-to-space), or space research (active) services. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government in the radiolocation service.
13 cm	Entire band	Not specified.	Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by other nations in fixed and mobile services. Amateur stations transmitting in the 2305–2310 MHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the FCC in the fixed, mobile except aeronautical mobile, and radiolocation services. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the radiolocation service. Amateur stations receiving in the 2400–2450 MHz segment must accept interference from industrial, scientific, and medical (ISM) equipment.
9 cm	Entire band	Not specified.	Amateur stations transmitting in the 3.4–3.5 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the fixed and fixed-satellite (space-to-Earth) services. Amateur stations transmitting in the 3.3–3.4 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the radiolocation service. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government

			in the radiolocation service. Amateur stations transmitting in the 3.332–3.339 GHz and 3.3458–3.3525 segments must not cause harmful interference to stations in the Earth exploration-satellite service (passive) or the space research service (passive).
5 cm	Entire band	Not specified.	Amateur stations transmitting in the 5.650–5.725 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the mobile except aeronautical mobile service. Amateur stations transmitting in the 5.65–5.85 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by other nations in the radiolocation service. Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government in the radiolocation service. Amateur stations transmitting in the 5.850–5.925 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the FCC and other nations in the fixed-satellite (Earth-to-space) and mobile services and also stations authorized by other nations in the fixed service. In the United States, the use of mobile service is restricted to Dedicated Short Range Communications operating in the Intelligent Transportation System. \ Amateur stations receiving in the 5.725–5.875 GHz segment must accept interference from industrial, scientific, and medical (ISM) equipment.
3 cm	Entire band	Not specified.	Amateur stations must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government in the radiolocation service. For amateur stations located in ITU Regions 1 and 3: Amateur stations transmitting in the 10.00– 10.45 GHz segment must not cause harmful interference to, and must accept interference from, stations of other nations in the fixed and mobile services.
1.2 cm	Entire band	Not specified.	Amateur stations transmitting in the 24.05–24.25 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government in the radiolocation service.

			Amateur stations must accept interference from industrial, scientific, and medical (ISM) equipment.
6 mm	Entire band	Not specified.	
4 mm	Entire band	Not specified.	Authorization of the 76–77 GHz segment for amateur station transmissions is suspended until such time that the Commission may determine that amateur station transmissions in this segment will not pose a safety threat to vehicle radar systems operating in this segment. Amateur stations transmitting in the 76–77.5 GHz segment, the 78–81 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government, the FCC, or other nations in the radiolocation service.
2.5 mm	Entire band	Not specified.	Amateur stations transmitting in the 2.5 mm band must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government, the FCC, or other nations in the fixed, inter-satellite, or mobile services. Amateur stations transmitting in the 136–141 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government, the FCC, or other nations in the radiolocation service. Amateur stations must accept interference from industrial, scientific, and medical (ISM) equipment.
1 mm	Entire band	Not specified.	Amateur stations transmitting in the 241–248 GHz segment must not cause harmful interference to, and must accept interference from, stations authorized by the United States Government, the FCC, or other nations in the radiolocation service. Amateur stations receiving in the 244–246 GHz segment must accept interference from industrial, scientific, and medical (ISM) equipment.
Above 275 GHz	Entire band	Not specified.	Amateur stations transmitting in the following segments must not cause harmful interference to radio astronomy stations: 275–323 GHz, 327–371 GHz, 388–424 GHz, 426–442 GHz, 453–510 GHz, 623–711 GHz, 795–909 GHz, or 926–945 GHz. In addition, amateur stations transmitting in the following segments must not cause harmful interference to stations in the Earth exploration-satellite service (passive) or the space

			research service (passive): 275–277 GHz, 294–306 GHz, 316–334 GHz, 342–349 GHz, 363–365 GHz, 371–389 GHz, 416–434 GHz, 442–444 GHz, 496–506 GHz, 546–568 GHz, 624–629 GHz, 634–654 GHz, 659–661 GHz, 684–692 GHz, 730–732 GHz, 851–853 GHz, or 951–956 GHz.

80. Strike 97.307(f) (1) through (13).

81. Amend Section 97.309(a) to read:

Any digital code that is fully disclosed to the public in sufficient detail that a knowledgeable person can create a computer program to encode and decode it, or any digital code of a type specifically authorized in this part, may be transmitted.

82. Strike Section 97.309 (1) through (4), as the change above makes them redundant.

C. “Large” Version of Regulatory Changes

83. In the “large” set of regulatory changes, FCC would delegate the task of designating the maximum bandwidth to be used per band-segment to the Radio Amateurs themselves. We suggest that such delegation include the text of our “medium” set of changes, but without specified bandwidths except for the 60 meter band. In addition FCC would designate a bandwidth coordinating agency for the United States, something like the volunteer examination coordinating agencies and repeater frequency coordinating agencies that currently are delegated tasks formerly performed by FCC.

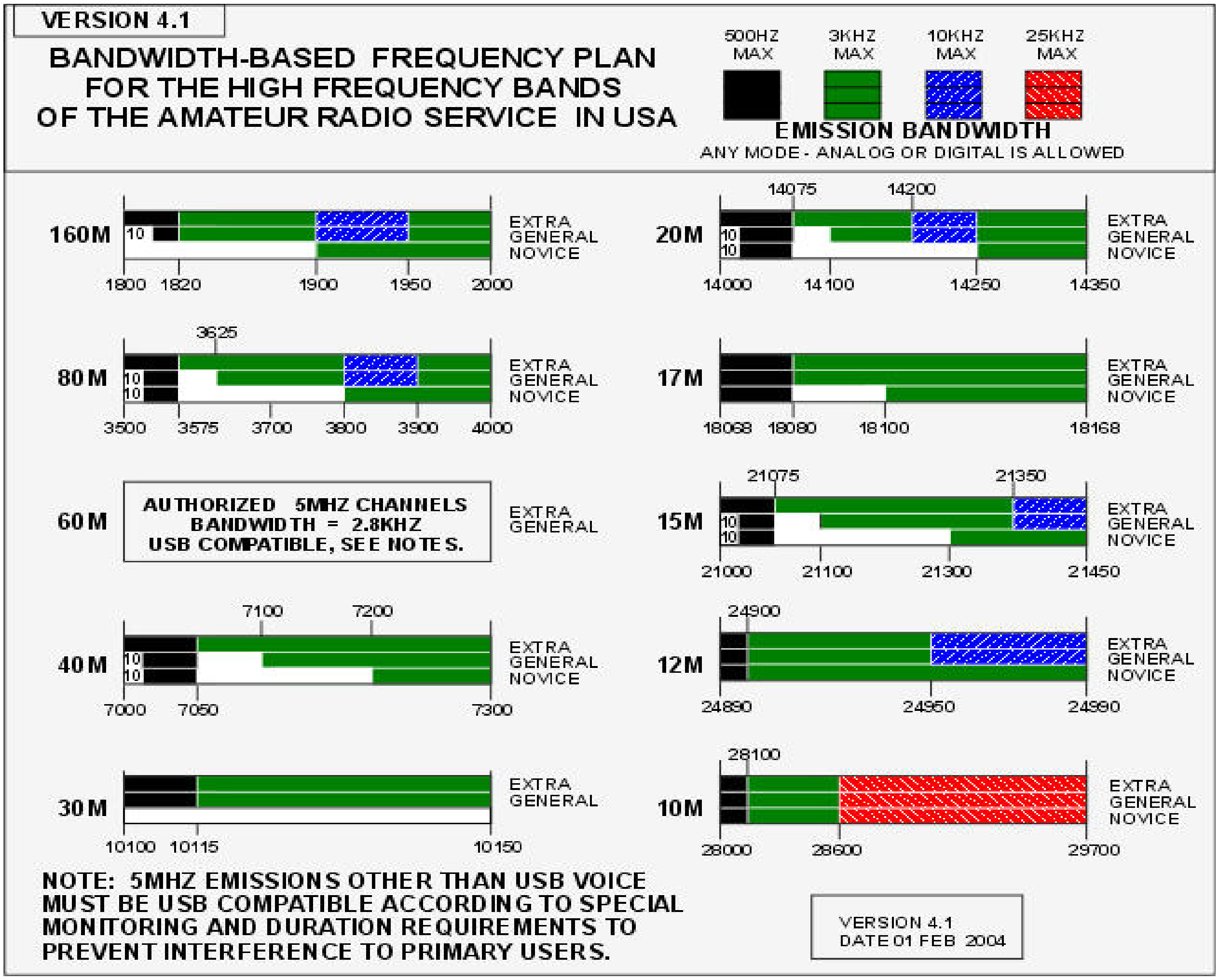
4. IN CLOSING

We respectfully submit this comment for the commission's consideration.

The Codec2 Project

Prepared by:
Bruce Perens
Perens LLC (not a law firm)
PMB 549
1563 Solano Ave.
Berkeley CA 94707
510-473-7367

Appendix A: HF Bandwidth-Based Band-Plan Designed by Bonnie Crystal KQ6XA



Appendix B: Current Modulation Details for FreeDV

Here are the current modulation details for the FreeDV program. Note that these are subject to change as the software is further developed.

FreeDV Specification

1. Introduction

FreeDV is a digital voice mode intended for transmission and reception over high-frequency (HF) radio. It uses a frequency division multiplex (FDM) modem with 15 carriers and no forward error correction (FEC). A low bit-rate voice coder-decoder (Codec 2) provides voice quality without the listener fatigue caused by noise and interference normally associated with analog single sideband (SSB) voice. Setup and operation of the Windows® and Linux compatible program was developed to make operation straightforward. A HF SSB transceiver, personal computer and two sound cards are required. Path simulation and on-the-air HF testing have shown that decoding voice is possible at a signal-to-noise ratio of 4 dB.

All of the software for FreeDV is open source, including Codec 2, the FDMDV modem, and the FreeDV GUI program. The source code may be referred to for further explanation of the mode and algorithms employed.

The FreeDV software was developed by David Rowe (Codec 2, FDM modem implementation, integration) and David Witten (GUI, architecture design). The FreeDV design and user interface was based on the earlier FDMDV program which was developed by Francesco Lanza. The FDM modem design and development was supported from Peter Martinez.

2. Waveform and Emission Designator

The waveform consists of 14 differential quadrature phase-shift keying (DQPSK) carriers with 75-Hz spacing between centers and a total bandwidth of 1.125 kHz. A differential binary phase-shift keying (DBPSK) carrier is centered between the 14 DQPSK carriers, making the total of 15 carriers. The DBPSK carrier has approximately twice the power of the 14 DQPSK carriers and is used for frequency offset estimation and frame synchronization. The carriers operate at 50 symbols/s (50 baud) each. Combined, they carry the Codec 2 voice data, call sign text data, and synchronization information.

3. Data Rate

14 DQPSK carriers at 50 symbols/second and 2 bits/symbol + 1 DBPSK carrier at 50 symbols per second = 14 x 2 x50 + 1 x 50 = 1450 bit/s total comprising 1375 bit/s Codec 2 data + 25 bit/s text data + 50 bit/s frame synchronization.

4. Frequency Tolerance and Correction

The FreeDV modulator is accurate to within +/- 5 Hz. The FreeDV demodulator can automatically acquire signals with a frequency offset of up to ±200 Hz. Manual tuning is also possible using mouse clicks on the waterfall and spectrum displays. Automatic frequency control (AFC) is capable of correcting frequency drift of up to 50 Hz/minute.

5. Frame Structure

Codec 2 Frame: 25 Hz, 40 ms, 55 bits/frame
Text Frame: 25 Hz, 40 ms, 1 bit/frame
Data Frame: 50 Hz, 20 ms, 14 carriers X 2 bits per symbol = 28 bits/frame.

Voice and Text to Data Frame mapping:

The modulator and demodulator operate on Data Frames of 28 bits. Two Data Frames comprise one

Codec Frame (55 bits) and one Text Frame (1 bit) intended for call sign identification. A DBPSK symbol with a 180 degree phase change from the previous symbol indicates the first data frame which carries the first 28 bits of the Codec2 Frame. The second Data Frame will have a DBPSK symbol with no phase change, and contains the last 27 bits of the Codec 2 Frame and the 1 bit Text Frame.

Text is encoded with Varicode. The following table maps the binary Varicode to ASCII (source file name varicode_table.h). The MSB is sent first, and there are two binary zeros between each Varicode character.

```
0b10101010,
0b11000000, // 0 NUL
0b10110110,
0b11000000, // 1 SOH
0b10111011,
0b01000000, // 2 STX
0b11011101,
0b11000000, // 3 ETX
0b10111010,
0b11000000, // 4 EOT
0b11010111,
0b11000000, // 5 ENQ
0b10111011,
0b11000000, // 6 ACK
0b10111111,
0b01000000, // 7 BEL
0b10111111,
0b11000000, // 8 BS
0b11101111,
0b00000000, // 9 HT
0b11101000,
0b00000000, // 10 LF
0b11011011,
0b11000000, // 11 VT
0b10110111,
0b01000000, // 12 FF
0b11111000,
0b00000000, // 13 CR
0b11011101,
0b01000000, // 14 SO
0b11101010,
0b11000000, // 15 SI
0b10111101,
0b11000000, // 16 DLE
0b10111101,
0b01000000, // 17 DC1
0b11101011,
0b01000000, // 18 DC2
0b11101011,
0b11000000, // 19 DC3
0b11010110,
0b11000000, // 20 DC4
```

```
0b11011010,
0b11000000, // 21 NAK
0b11011011,
0b01000000, // 22 SYN
0b11010101,
0b11000000, // 23 ETB
0b11011110,
0b11000000, // 24 CAN
0b11011111,
0b01000000, // 25 EM
0b11101101,
0b11000000, // 26 SUB
0b11010101,
0b01000000, // 27 ESC
0b11010111,
0b01000000, // 28 FS
0b11101110,
0b11000000, // 29 GS
0b10111110,
0b11000000, // 30 RS
0b11011111,
0b11000000, // 31 US
0b10000000,
0b00000000, // 32 SP
0b11111111,
0b10000000, // 33 !
0b10101111,
0b10000000, // 34 "
0b11111010,
0b10000000, // 35 #
0b11101101,
0b10000000, // 36 $
0b10110101,
0b01000000, // 37 %
0b10101110,
0b11000000, // 38 &
0b10111111,
0b10000000, // 39 '
0b11111011,
0b00000000, // 40 (
0b11110111,
0b00000000, // 41 )
0b10110111,
0b10000000, // 42 *
0b11101111,
0b10000000, // 43 +
0b11101010,
0b00000000, // 44 ,
0b11010100,
```

```
0b00000000, // 45 -
0b10101110,
0b00000000, // 46 .
0b11010111,
0b10000000, // 47 /
0b10110111,
0b00000000, // 48 0
0b10111101,
0b00000000, // 49 1
0b11101101,
0b00000000, // 50 2
0b11111111,
0b00000000, // 51 3
0b10111011,
0b10000000, // 52 4
0b10101101,
0b10000000, // 53 5
0b10110101,
0b10000000, // 54 6
0b11010110,
0b10000000, // 55 7
0b11010101,
0b10000000, // 56 8
0b11011011,
0b10000000, // 57 9
0b11110101,
0b00000000, // 58 :
0b11011110,
0b10000000, // 59 ;
0b11110110,
0b10000000, // 60 <
0b10101010,
0b00000000, // 61 =
0b11101011,
0b10000000, // 62 >
0b10101011,
0b11000000, // 63 ?
0b10101111,
0b01000000, // 64 @
0b11111010,
0b00000000, // 65 A
0b11101011,
0b00000000, // 66 B
0b10101101,
0b00000000, // 67 C
0b10110101,
0b00000000, // 68 D
0b11101110,
0b00000000, // 69 E
```

```
0b11011011,
0b00000000, // 70 F
0b11111101,
0b00000000, // 71 G
0b10101010,
0b10000000, // 72 H
0b11111110,
0b00000000, // 73 I
0b11111110,
0b10000000, // 74 J
0b10111110,
0b10000000, // 75 K
0b11010111,
0b00000000, // 76 L
0b10111011,
0b00000000, // 77 M
0b11011101,
0b00000000, // 78 N
0b10101011,
0b00000000, // 79 O
0b11010101,
0b00000000, // 80 P
0b11101110,
0b10000000, // 81 Q
0b10101111,
0b00000000, // 82 R
0b11011110,
0b00000000, // 83 S
0b11011010,
0b00000000, // 84 T
0b10101011,
0b10000000, // 85 U
0b11011010,
0b10000000, // 86 V
0b10101110,
0b10000000, // 87 W
0b10111010,
0b10000000, // 88 X
0b10111101,
0b10000000, // 89 Y
0b10101011,
0b01000000, // 90 Z
0b11111011,
0b10000000, // 91 [
0b11110111,
0b10000000, // 92 "\"
0b11111101,
0b10000000, // 93 ]
0b10101111,
```

```
0b11000000, // 94 ^
0b10110110,
0b10000000, // 95 _ (underline)
0b10110111,
0b11000000, // 96 `
0b10110000,
0b00000000, // 97 a
0b10111110,
0b00000000, // 98 b
0b10111100,
0b00000000, // 99 c
0b10110100,
0b00000000, // 100 d
0b11000000,
0b00000000, // 101 e
0b11110100,
0b00000000, // 102 f
0b10110110,
0b00000000, // 103 g
0b10101100,
0b00000000, // 104 h
0b11010000,
0b00000000, // 105 i
0b11110101,
0b10000000, // 106 j
0b10111111,
0b00000000, // 107 k
0b11011000,
0b00000000, // 108 l
0b11101100,
0b00000000, // 109 m
0b11110000,
0b00000000, // 110 n
0b11100000,
0b00000000, // 111 o
0b11111100,
0b00000000, // 112 p
0b11011111,
0b10000000, // 113 q
0b10101000,
0b00000000, // 114 r
0b10111000,
0b00000000, // 115 s
0b10100000,
0b00000000, // 116 t
0b11011100,
0b00000000, // 117 u
0b11110110,
0b00000000, // 118 v
```

```
0b11010110,
0b00000000, // 119 w
0b11011111,
0b00000000, // 120 x
0b10111010,
0b00000000, // 121 y
0b11101010,
0b10000000, // 122 z
0b10101101,
0b11000000, // 123 {
0b11011101,
0b10000000, // 124 |
0b10101101,
0b01000000, // 125 }
0b10110101,
0b11000000, // 126 ~
0b11101101,
0b01000000, // 127 (del)
```

6. Modem

The modem uses a raised-cosine tone filter response having the property of zero inter-symbol interference (ISI) and zero adjacent tone interference with no side lobes. Half the channel filter is in the transmit (TX) side and the other half in the receive (RX) side. It may be called "root raised cosine" because the channel filters at each end have the net response of a square-root of the complete filter. A 50% excess bandwidth factor is used. The demodulator also performs initial frequency acquisition, frame synchronization, timing offset estimation, and frequency tracking of the FDM signal.

9. Acknowledgement

This description was prepared by Mel Whitten, KØPFX, and David Rowe, VK5DGR.