ENHANCED CROWDSOURCING FOR DISASTERS THROUGH HAM-RADIO OPERATORS

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***Abstract**: This paper describes an enhanced crowdsourcing that may be the only alternative when everything else fails in a disaster. This scheme requires radio operators that can work not only together with other communications media (such as the Internet and wireless phones), but they can also work on their own, if the other media either fail or do not exist in the area. In order to increase the number of such radio operators, a scheme for accelerated radio education and training is required. This paper describes the structure of such a course, its delivery, demonstrations, workshops, and examination that lead to a government-issued Radio Operator's Certificate. The course has evolved over the last 25 years.*

***Keywords**:* Humanitarian technology for disasters; enhanced crowdsourcing; ham radio education and training.

1. INTRODUCTION

This planet has been experiencing many natural and human-made disasters and emergencies. The natural disasters include earthquakes, tsunamis, floods, fires, and the spread of infectious diseases, and are characterized by unpredictability and large geographical areas. The human-made disasters include gas pipeline explosions, oil pipeline spills, cargo-rail oil spills, and cargo-ship oil spills, and are also characterized by unpredictability, but with a more localized impact.

Many disaster response schemes have been developed to cope with the complexity of those conditions. *Crowdsourcing* has been gaining popularity due to the availability of technology such as Internet and personal wireless communications. Crowdsourcing refers to gathering vital information, content, solutions, and services from a large number of individuals connected through different means of wired and wireless communications. Most of today's crowdsourcing definitions include the Internet as the connectivity medium (e.g., [Merr13], [Howe06a], [Howe06b], [Howe09], [Brun11], [Safi09], [Brab08], [EsGo12], [Wiki14]).

This paper describes an enhanced crowdsourcing that may be the only alternative when everything else fails in a disaster. This scheme requires radio operators that can work not only together with other communications media (such as the Internet and wireless phones), but that they can also work on their own, if the other media either fail or do not exist in the area. In order to increase the number of such radio operators, a scheme for accelerated radio education and training is required. This paper describes the structure of such a course, its delivery, demonstrations, workshops, and examination that lead to a government-issued Radio Operator's Certificate. The course has evolved over the last 25 years [Kins14].

This paper presents a scheme that uses radio communications to achieve the goal of crowdsourcing during natural and human-made disasters.

2. HAM CROWDSOURCING

The common crowdsourcing relies on wired/wireless phones and the Internet to collect vital information about a problem from many diverse individuals, as shown in Fig. 1. This method has been used in many situations (see some of the references listed in the previous section). However, crowdsourcing is not feasible when the standard communication media are either not available, or overloaded, or destroyed.

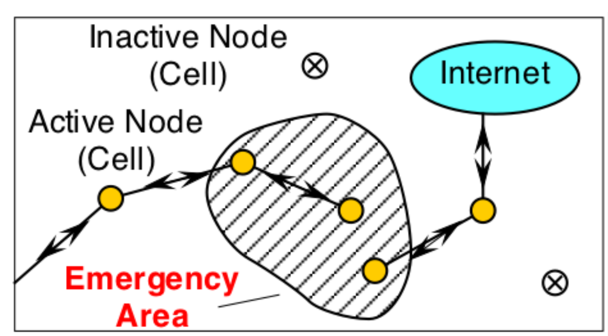

Fig. 1 Terrestrial and Internet crowdsourcing.

Typhoons and tornados can damage power lines (the mains), cell-phone towers, telephone landlines, as well as cable telephones and the Internet. Even if the systems are not destroyed, they can be overloaded as happened during hurricane Katrina and the Boston Marathon. Ham radio can run on the mains and on 12-V batteries (car, motorcycle, dry cells), or solar cells, wind generators, and gas emergency generators.

There are many examples where ham radio has been used in such situations when all other means have failed. For example, a tornado touched down in Edmonton, Alberta on July 31, 1987 for an hour. Its path of 40×1 km (25×0.6 mi) killed 27 people and caused damage of nearly $600 M (in 2014 dollars). This tornado was considered to be EF4 on the Extended Fujita scale.

The strongest EF5 tornado in Canada touched down in Elie, Manitoba on June 22, 2007, causing damage of $43 M (in 2014 $). In both cases, ham operators were the first to report the events, even though not all communication media were destroyed. The problem is much more severe in the USA because the average number of tornadoes per year is 1,200, as compared to 230 in Canada.

A more recent typhoon Haiyan (Yolanta) that reached the central Philippines on November 8, 2013 destroyed nearly all essentials, including food, water, shelter, electrical power, and the cell-phone system, while killing over 6 thousand people. Hams were the only individuals who could work with government and military organizations (the Philippine Amateur Radio Association, PARA and the Ham Emergency Radio Operations, HERO) to help in this disaster, starting from Facloban (Leyte Island) and elsewhere.

The key to ham radio is that the operators can use not only terrestrial communications by also HF radio that covers the entire globe, as shown in Fig 2.

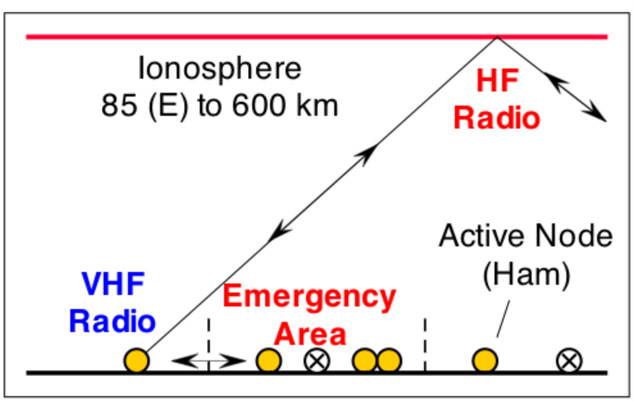

Fig. 2 Ham radio crowdsourcing.

Figure 3 shows the enhanced ham crowdsourcing concept. While the regular ham emergency operations are in place (terrestrial VHF, HF and satellite channels), we add a new form of operations through unmanned aerial vehicles (UAVs) called ORBO, located at 0.1 to 3 km (400 to 9,800 ft) above ground. The drones can maintain themselves there for the duration of the emergency. The fundamental advantage of the ORBO drones is that they can be deployed easily, can communicate with other drones, thus providing an extension of the horizon of the ham radio communications.

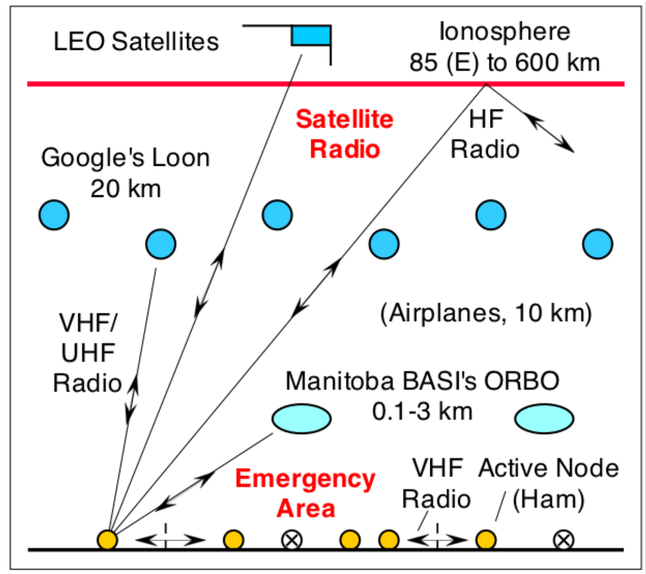

Fig. 3 Enhanced ham crowdsourcing (not to scale).

In 2014, Google-X announced its Project Loon intended to provide WiFi connectivity to remote locations by launching high-altitude balloons (HABs) with solar cells and transponders. The HABs will fly in the stratosphere 20 km (66,000 ft) above ground where wind currents are fast (40 km/h (25 mph), and will stay there for about 100 days. The target installation date for the project is 2020.

Mark Zuckerberg of Facebook is also working on similar HAB drones also placed at 20 km to provide Internet connection to remote locations, with a lifespan of 5 years. Target completion date is 2015.

3. Background on Ham Radio

3.1 What is Ham Radio?

Amateur radio (also known as ham radio) refers to voice and data communications over radio frequency bands that are free to individuals who have passed qualifying exams to operate on those bands. Ham radio is both (i) hobby, (ii) education, and (iii) service, but it cannot be used for commercial or revenue-generating purposes. As a **hobby**, ham radio provides extreme opportunities to communicate with others from any place and any time (even where is no Internet or any other means of distance communication). As an **education** means, ham radio provides great opportunities to engage in self-study and discovery of the best modes and practices in communications. Finally, as a **service**, ham radio provides public service in many situations when all other means fail. There are many books and magazines describing ham radio from several perspectives, including technical and operational (e.g., [Wils09], [Davi90]).

3.2 Why the Quest to Become a Ham?

3.2.1 Operations: The prime reason is to learn how to communicate under any conditions, a very valuable skill to have for a lifetime. To do so, we must know the different frequency band allocations and their behavious at different times of the day and night. For example, the high-frequency (HF) bands, such as the 14-MHz or 20-m band; the very-high-frequency (VHF) bands such as the popular 144-MHz or 2-m band; ultra-high-frequency(UHF) bands such as the 430-MHz or 70 cm band; and many others.

3.2.2 Operating Modes: In addition, a ham must know various analog and digital operating modes such as the amplitude modulation (AM), frequency modulation (FM), phase modulation (PM), amplitude-shift keying (ASK), frequency-shift keying (FSK), phase-shift keying (PSK) and its variations (PSK31, PSK63), as well as quadrature-amplitude modulation (QAM) with many of its variants. The digital modes require knowledge of various protocols, such as packet (AX.25), automatic packet reporting system (APRS), and amateur teleprinting over radio (AMTOR, SITOR, RTTY).

3.2.3 Signal Transmission Schemes: A ham radio operator must also know how different signal transmission schemes operate, including the double band with carrier (AM), double-sideband with suppressed carrier (DSB-SC), single sideband (SSB), continuous wave (CW) or Morse code, and spread spectrum (SS).

3.2.4 Satellite Communications: The ability to communicate over amateur radio satellites is becoming very popular due to the number of such satellites and many nano- and pico-satellites that hams can build today. For example, together with a colleague, I established a team of over 100 students and over 50 advisors at the University of Manitoba to design, build, test, and launch a nano-satellite. We are now in the second generation of the satellite development. Such satellites are placed into a low-Earth orbit (LEO) at 160 to 2,000 km, with 15 to 16 revolutions per day, and 9 to 17 minute horizon-to-horizon acquisition. A very capable satellite ground station for satellite and near-space communications has also been completed.

3.2.5 Signal Processing: Today's communications require good knowledge of signal processing, including time analysis (e.g., autocorrelation and cross-correlation), spectral analysis (e.g., Fourier transform), multiscale analysis (e.g., wavelet transform), and polyscale analysis (for self-affine signals) [Kins13d]. This requires familiarity with stochastic signals, uncertainty management, and intelligent signal processing.

3.2.6 Tinkering: The greatest joy of a ham is the ability to build their own equipment such as antennas, low power (QRP) transmitters and receivers (transceivers), wireless sensing netwoks, wireless communication networks for autonomous rolling and flying robots, software-defined radio (SDR), and transponders for pico-satellites.

3.2.7 Team Operations: Another reason to become a ham operator is to participate in numerous activities with other hams in amateur radio clubs, field days, fox hunting, geocaching, and contests.

3.3 What Should a Ham Know?

As just described, a ham should know (i) regulations, (ii) theory, and (iii) practice. The **regulation** (specific to each country) include: bands assigned to hams, power allowed on each band while using a specific mode of operation, and operating procedures that are acceptable and efficient. The **theory** includes electromagnetic wave propagation, generation and reception under different conditions through electric circuits and electronic circuits, as well as receivers and transmitters. The **practice** includes the best operating procedures, safety under different operating conditions, examples of equipment used in radio (antennas, transceivers, testers), and demonstrations of different classes of radio equipment.

4. COURSE STRUCTURE

This course has been developed over many years, with continuous improvements based on the yearly delivery of the course to university students, practising engineers, and some high-school students. The structure of the course was also affected by the technology available and the facilities available at the university.

4.1 Mentor-Oriented Teaching

A standard radio course is intended for an audience whose technical preparation is minimal, and requires careful crafting of the material so that most of the students would know the basics, pass the exam, and operate radio equipment safely. The audience in this accelerated course has extensive experience (many university or college courses) or capabilities to learn the material with the help of a high-school teacher, or a mentor from the radio community. The instructor in the course is a mentor to all, while other mentors provide continuous help in the learning process. The key mentors for the course were also members of the local university club. Those hams also played a critical role in the demonstrations after each session.

4.2 Modular Delivery

The course is split into seven logical evolutionary units. The first U1-Orientation Unit, is followed by the core of the course: U2-Regulation; U3-Operating; U4-Passive circuits; U5-Propagation and antennas; U6-Active circuits; U7-Analog and digital modulation techniques. Each session has two hours of presentation and discussion of the core concepts.

Each session is followed by a demonstration, as described later in this paper.

The exam is conducted one month after the course. It includes 100 questions taken from the question bank [RIC707]. A passing mark for the Basic Qualifications is 70%, and 80% for Basic Qualifications with Honours (access to HF bands). The second exam is conducted five months later. If a person does not pass in two takes, they have to take the exam at the government premises (Industry Canada).

4.3 Syllabus Summary

The main topics covered include: (1) Motivation and introduction, (2) Regulations: ham bands, Q-codes, band-plans; (3) Operation on ham bands; (4) Electrical passive components (R, L, C) and electric circuits; (5) Electronic active components and electronic circuits; (6) Radio wave propagation; (7) Transmission lines in radio; (8) Antennas (types and properties); (9) Modulating, receiving, and amplifying electronic components; (10) Radio transmitters and receivers (CW, AM, SSB, FM); (11) Ham station, interference, safety; and (12) Demonstrations (throughout the course).

4.4 Syllabus in More Detail

This section lists the required topics, but its arrangement in the actual notes has a unique flavour that allows flexibility to either expand or reduce the material covered in class, depending on the actual audience.

4.4.1 Rules and Regulations: The key topics include (e.g., [RBR407], [RIC305]): Radio authorization; enforcement; certificates; privileges; standards; restrictions; installation and qualifications; using amateur radio stations; harmful interference; emergency communications; remuneration and privacy; identification; third party communications; qualifications and HF bands; bandwidth; power restrictions; unmodulated carriers and retransmissions; measurements; International Telecommunications Union (ITU) ; ITU regions and CEPT; examinations; antenna structures; RF field limits; and resolution of complaints.

4.4.2 Operating Procedures: The key topics include: Phonetic alphabet; courteous operating; repeater operating procedures; simplex and HF operating procedures; operating CW; RST system (R -readability; S -strength; T -tone); Q signals; emergency procedures and operator aids.

4.4.3 Basic Electricity: The key topics include: Types of materials (conductors, semiconductors, insulators); electricity, charges, mobility; resistance and conductance; power and circuits; Ohm's law; series and parallel circuits power; alternating current; decibel; magnetostatic and electrostatic fields as forces; inductance and capacitance; reactance; magnetism and transformers; resonance; meters; and measurements.

4.4.4 Electronic Circuit Fundamentals: The key topics include: Diodes; transistors; amplifiers, classes of amplifiers and their properties; field effect transistors; complementary metal-oxide semiconductors (CMOS); and vacuum tubes.

4.4.5 Functional Layout and Safety: The key topics include: HF station components; FM transmitter; FM receiver; CW transmitter; SSB/CW receiver; SSB transmitter; digital systems; regulated power supply; antenna; receiver fundamentals; transmitter fundamentals; single-sideband fundamentals; FM fundamentals; station accessories; digital fundamentals; batteries; power supplies; hazards and safety; grounding; antenna and towers; and RF exposure.

4.4.6 EM Wave Propagation: The key topics include: Electromagnetic waves and their nature; Maxwell's equations with divergence and curl operators, solar activity; ionosphere; skip zone; fading; critical and maximum usable frequency; ducting and sporadic-E; and scatter propagation; predicting propagation and quality of communications for a given location, time, and distance.

4.4.7 Antenna Systems: The key topics include: Transmission lines; balanced and unbalanced transmission lines; cables and connectors; feed lines; voltage standing wave ratio (VSWR); impedance matching; antenna polarization; wavelength; antenna terms; horizontal (Hertz) antennas,; vertical (Marconi) antennas; Yagi-Uda antennas; long-wire antennas; quad and loop antennas; specific antenna types.

4.4.8 Interference Suppression: The key topics include: Front-end overload and cross modulation; audio rectification; spurious emissions and key clicks; harmonics and splatter; filters.

4.5 Demonstrations

Each session concluded with a demonstration of equipment or operations. The demonstrations varied from year to year. The demonstrations on equipment were short, while operations took much longer and in different locations.

4.5.1 Radio Equipment Demo: This first demo focused on ham radio equipment such as linear power supply, radio transmitter, receiver (both handheld, mobile, and base station), antennas (Hertz, Marconi, J-pole, Yagi, portable), antenna wires and rods (stranded, solid), antenna insulators (end, centre), cables (CAT-5e, CAT-6, optical fibre), transmission lines (T-lines) types (e.g., RG-8/U, RG-58, RG142, heliax), cable connectors (PL-259, BNC, SMC), adapters between various connectors, different types of radio components (coils, capacitors, resistors), transmitter-antenna match, low-pass filter, power meter, standing-wave ratio SWR) meter, frequency meter, high-quality and standard microphones, radio loudspeakers. The demo must be well crafted so as to bring the components to the students, without overwhelming them.

4.5.2 Preparing for a QSO Demo: This activity demonstrated a handheld radio transceiver (TxRx) must be prepared for the "My-first-QSO" session. In the past, expensive radio units were used ($300), and some of them were lost due to excessive handling. We have recently switched to inexpensive transceivers ($40) so that not only the course would have a few of them, but the students could also purchase them for their own study and use. The setting and programming of the units is quite complicated, and the demo was necessary to show how to prepare the radios for the communication (QSO) session.

4.5.3 The First QSO Demo: This demo started from a discussion on the different QSOs that can be conducted. It has presented a QSO protocol with many examples of (i) how to make sure that the frequency is not in use, (ii) how to start a QSO, (iii) how to report on signal strength and readability, (iv) how to conduct the conversation, and (v) how to end the QSO. Confirmation of the QSO was also demonstrated with QSL cards and other means. It emphasized the non-invasive listening mindset.

4.5.4 The Second QSO Demo: This demo reinforced the operational skills of students, including the push-to-talk (PTT), delay, talk, delay, and PTT cycle in a point-to-point communication and communication through a repeater. It started from both operators being in the same room in order to acquire more familiarity with the equipment and with the operations. The next stage moved one of the operators into another room to learn the impact of metal walls in the building on the quality of the signal. The third stage moved the operator outside the building to experience fading and signal deterioration.

3.5.5 Satellite Ground Station Demo: This demo presented the complexity of a ground station, its equipment, satellite location and tracking software, and a procedure to communicate in extreme conditions.

4.5.6 APRS Demo: The automatic packet reporting system (APRS) has become quite popular because of its utility and fusing of wired and wireless communication networks. Its equipment and operations were demonstrated.

4.5.7 Fox Hunting Demo: Finding and locating illegally operating transmitters is a useful skill, as it eliminates transmitters that are left on unintentionally, and it involves triangulation of signal with directional antennas, multipath (reflections from tall buildings) misleading readings, signal fading, receiver overloading when the seeker gets too close to the fox, and time constraints (the shortest time wins).

5. Concluding Remarks

This paper provides a summary of traditional crowdsourcing, and proposes a new class of enhanced crowdsourcing through ham operations that include not only VHF/UHF/HF frequency bands to communicate locally and globally without the Internet, but also a new layer of UAVs (drones) to provide further connectivity beyond the terrestrial horizon. Such UAVs are being developed in Manitoba, and elsewhere (different models). In order to implement such a new scheme, more radio operators are required. The paper also presents an intensive ham radio course to help in developing the new skills.

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References

[Brab08] Daren Brabham, "Crowdsourcing as a model for problem solving: An introduction and cases", convergence," *Intern. J. of Research into New Media Technologies*, vol. 14, no. 1, pp. 75–90, 2008. Retrieved 12 January 2014 from http://www.clickadvisor.com/downloads/Brabham_Crowdsourcing_Problem_Solving.pdf

[Brun11] Elena Bruno, "Smithsonian crowdsourcing since 1849!" *The Bigger Picture, Smithsonian Institution Archives*, Apr 14, 2011. Retrieved 12 January 2014 from http://siarchives.si.edu/blog/smithsonian-crowdsourcing-1849

[Davi90] Martin Davidoff, K2UBC, *The Satellite Experimenter's Handbook*. Newington, CT: ARRL, 1990, 343 pp. {ISBN 0-87259-004-6 pbk}

[EsGo12] Enrique Estellés-Arolas and Fernando González-Ladrón-de-Guevara, "Towards an integrated crowdsourcing definition", *J. Information Science*, vol. 38, no. 2, pp. 189–200, 2012. Retrieved 12 January 2014 from http://www.crowdsourcing-blog.org/wp-content/uploads/2012/02/Towards-an-integrated-crowdsourcing-definition-Estell%C3%A9s-Gonz%C3%A1lez.pdf

[Howe06a] Jeff Howe, "The rise of crowdsourcing," *Wired Mag*, vol. 14, no. 6, June 2006. Retrieved 12 January 2014 from http://www.wired.com/wired/archive/14.06/crowds.html

[Howe06b] Jeff Howe, "Crowdsourcing: A definition," *Crowdsourcing Blog*, Jun 2, 2006. Retrieved 12 January 2014 from http://crowdsourcing.typepad.com/cs/2006/06/crowdsourcing_a.html

[Howe09] Jeff Howe, *Crowdsourcing: Why the Power of the Crowd Is Driving the Future of Business*. New York, NY: Random House, 2009, 336 pp. {ISBN: 978-0-307-39621-1} Retrieved 12 January 2014 from http://www.randomhouse.com/book/83579/crowdsourcing-by-jeff-howe/9780307396204/

[Kins14] Witold Kinsner, *Radio Theory and Practice*. Winnipeg, MB: University of Manitoba, 2013, 250 pp. (Originally published by the Canadian Radio Relay Federation, 1990, 145 pp.).

[Kin13a] Witold Kinsner, *Microcontroller, Microprocessor, and Microcomputer Interfacing for Real-Time Systems*. Lecture Notes. Winnipeg. MB: University of Manitoba, 2013, 643 pp.

[Kin13b] Witold Kinsner, *Laboratories for Microcontroller, Microprocessor, and Microcomputer Interfacing for Real-Time Systems*. Lab Notes; 2013, 102 pp.

[Kins13c] Witold Kinsner, *The HCS12 Microcontroller: A Tutorial*. Winnipeg. MB: University of Manitoba, 2013, 66 pp.

[Kins13d] Witold Kinsner, *Fractal & Chaos Engineering*. Lecture Notes. Winnipeg, MB: University of Manitoba, 2013, 941 pp.

[Kins90] W. Kinsner, VE4WK, *Radio Theory, Morse Code and Projects*. Radio Amateurs of Canada, RAC, 1990.

[Kins92] W. Kinsner, VE4WK, *Q-Bank for Basic Qualifications*. OCO Research, 1992.

[Merr13] Merriam Webster Dictionary, 2013. Retrieved 12 January 2014 from http://www.merriam-webster.com/dictionary/crowdsourcing

[RBR407] RBR-4, *Standards for the Operation of Radio Stations in the Amateur Radio Service.* Industry Canada, Issue 1, May 2007, 11 pp. (Formerly RIC-2, Issue 5, July 2005) http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01226.html

[RIC305] RIC-3, *Information on the Amateur Radio Service*. Industry Canada, Issue 3, July 2005, 18 pp. http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01008.html

[RIC707] RIC-7, *Basic Qualifications Question Bank for Amateur Radio Operator Certificate Examinations*. Industry Canada, Issue 3, April 1, 2007, 118 pp. http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01900.html

[Safi09] William Safire, "On language," *New York Times Mag*, Feb 5, 2009. Retrieved 12 January 2014 from http://www.nytimes.com/2009/02/08/magazine/08wwln-safire-t.html?_r=4&ref=magazine&

[Wiki14] Wikipedia, "Crowdsourcing," 2014. Retrieved 12 January 2014 from http://en.wikipedia.org/wiki/Crowdsourcing

[Wils09] Mark J. Wilson (ed.), *The 2009 ARRL Handbook for Radio Communications*. Newington, CT: ARRL, 2009, 965 pp. {ISBN 0-87259-140-9 hbk}

Appendix A: Instructor

Delivery of such an intensive course requires theoretical background and practical experience with ham radio. The instructor (VE4WK) in this course has Basic Qualifications, Advanced Qualifications, and 12 words-per-minute (WPM) Morse code Qualification. He has written many research papers on new modes in amateur radio, supervised many final-year (capstone) projects, a book on radio theory and practice [Kins90], [Kins92], designed and implemented many radio related projects, including a VE4WK J-pole antenna now used in many locations, and taught many courses, workshops, and seminars. Although his radio base station is capable of operating at high power, he never uses more than 5 W (QRP), and often operates well below 1 W (QRPp), mostly CW and digital modes.

With colleagues, he developed a large satellite ground station at the University of Manitoba (UofM) for satellite communications and tracking of near-space experiments. He is the University Advisor to a triple pico-satellite (T-Sat) project at the UofM. He has been Director of the one-week Space Camp and a Verna Kirkness Camp for Indigenous students, both conducted each summer at the UofM. He is developing new communications systems and navigation systems for unmanned aerial vehicles.

He obtained many awards, including Worked All States on CW (WAS CW), WAS CW 40 (on the 40-m band), and WAS CW QRP. He is also a member of the Radio amateurs of Canada (RAC), American Radio Relay League (ARRL), and QRP Amateur Radio Club International (ARCI), ARRL Rag Chewers Club, Winnipeg Amateur Radio Club (WARC), University advisor to the University of Manitoba Amateur Radio Society (UMARS). He is also an Accredited Examiner for Industry Canada, Government of Canada.