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Progress with Digital Modes and Techniques in New Zealand

A Paper from the New Zealand Association of Radio Transmitters Incorporated (NZART) for Presentation at the 13th IARU Region 3 Conference Bangalore, India, August 2006

Introduction

This paper reports on current digital mode practice, and on the development of new digital modes and techniques in New Zealand over the last three years. Digital developments offer new frontiers and levels of performance in amateur radio, and provide a real technical challenge. New amateur radio developments continue to involve the use of computers and micro-controller devices as well as new conventional and digital components. This combination of new technology provides an attractive way of recruiting new people to the hobby, or retaining the attention of technically capable amateurs, with interesting new projects.

Digital modes, especially on LF and HF, have continued to increase in number and popularity since the last report (Document 04/XII/020, Taipei). New Zealand is uniquely suited to development of new modes, having advantages of geographic isolation, and thus less band crowding; and most importantly, a benign and encouraging attitude to development and on-air testing of new modes by the radio regulation agency in New Zealand, the Ministry of Economic Development.

Modes developed or designed in Region 3 continue to be of interest world-wide. There continues to be strong interest in "chat-type" narrow band modes, and in recently developed wide-band modes that offer good robustness and general performance. However, the latter cannot reasonably be used in crowded band segments. As with other modes, there continues to be difficulty in operating digital modes in some allocated segments of the bands, with unlicensed CB-type transmissions, Over-the-Horizon Radar intrusion and aggressive bulletin board services on inappropriate frequencies causing the most concern.

Popular Digital Modes

PSK31 continues to be the most popular "chat-type" digital mode, no doubt due to its simplicity and small bandwidth. Developed nearly 10 years ago, it continues to be the most popular mode for DX, despite recent advances in other modes. PSK31 lacks error correction and is not robust under adverse conditions, however. Insufficient transmitter linearity continues to be a problem with some users of this mode.

MFSK16, developed in New Zealand by Murray Greenman ZL1BPU and programmed first by Nino Porcino IZ8BLY, has now been in use on the bands for six years, and has a firm following among discerning DX chat-mode regulars. It offers excellent sensitivity, combined with high tolerance of Doppler and multi-path conditions, which have made it the mode of choice for long-path DX. MFSK16 is now available in numerous sound card programs for Windows[®] and Linux[®] computers. Its performance has not been seriously challenged until the arrival of "DominoEX", which will be described in more detail later in this paper.

MT63 and **OLIVIA** are relatively complex modes using multi-carrier wideband techniques. MT63 uses 64 PSK carriers, while OLIVIA uses MFSK, typically with 32 tones. In both cases a bandwidth of 1kHz is usual. These modes have reasonable sensitivity, and good performance despite interference from other modes, but they have poor turn-around speed and occupy a large bandwidth for their modest typing speed.

SSTV continues to be popular on HF and VHF, with most activity on 20 m. Digital SSTV, using the HAMDRM modem is slowly attracting interest. Those with sufficient computer power can use software such as HAMPAL and DIGTRX to transfer flawless pictures. However, conditions need to be good and the signal to noise ratio requirements are far more demanding than for analogue SSTV. Software for Digital SSTV continues to improve faster than the documentation!

New Digital Modes

It is with some pride that NZART can report the continued development in Region 3 of useful new digital modes with impressive performance. Recent developments span a wide range of interests, and include techniques ranging from simple to highly complex.

Castle

The simple 'CASTLE' mode for LF Morse transmission is a recent development, offering improved readability and a slight speed improvement over the more commonly used differential FSK Morse transmission. In each Castle mode character, repeated Morse dots are sent on increasing frequency steps, and dashes on decreasing frequency steps. Dots and dashes can be the same length, and this new technique avoids the need for spaces between repeated elements. Castle can be transmitted in many different ways, and is already available in the ZL1BPU LF Exciter design.

Coherent Reception

Work has begun on true carrier synchronous coherent reception techniques for LF. This is possible on LF since the reception path is relatively phase-stable. Recently developed algorithms from Peter Martinez G3PLX have enabled the LF receiver to be synchronized and locked in phase to a reference signal from a GPS receiver. The radio frequency harmonics of the 1 Hz pulse are analysed and used to digitally tune the software to compensate for phase and frequency errors in the receiver. Received signal level, frequency and phase can be measured with great accuracy independent of receiver performance.

This technique is incredibly sensitive. Using software developed by Con Wassilieff ZL2AFP and the G3PLX 'Clicklock' algorithms, a signal of 100 mW (4 uW EIRP) from ZL1BPU on 181.4 kHz has been detected at a range of 500 km. North American and European LF utility stations can now also be detected in New Zealand. All it takes is for the transmission to have very high carrier frequency precision, or be synchronized to GPS.

Murray Greenman, ZL1BPU, has developed a simple GPS-synchronous transmitter for these tests. A version of the well-known ZL1BPU LF Exciter, this transmitter has 1 W output, 0.3 milliHz frequency resolution, and transmits a carrier with GPS-locked precision.

DominoEX

This new digital mode is one of the most significant digital mode developments recently. It is described in some detail here. DominoEX is the result of nearly 18 months of research into the nature and propagation of "Near Vertical Incidence Signals" (NVIS). This included devising appropriate techniques for managing the signals, followed by six months of software development. DominoEX is a modestly narrow band MFSK mode, with some similarity to MFSK16, but with several performance enhancing innovations that set it apart.

DominoEX has marked improvement in robustness, especially against multi-path effects, such as are common on low HF at night. It has good sensitivity with improved rejection of impulse noise and carrier interference. The most remarkable difference, however, is its tolerance of drift and frequency error, always a problem with MFSK modes in the past.

Unlike previous MFSK modes, DominoEX codes the transmitted data incrementally, with an added fixed offset. Incremental Frequency Keying (IFK) was first suggested by Steve Olney VK2ZTO, and has been used on LF in JASON by Alberto de Bene I2PHD. The DominoEX offset IFK technique, dubbed 'IFK+' because of the added offset, uses 18 tones. It provides in one big step:

- High tolerance of drift and tuning errors, since the frequency of each tone is measured by difference from the previous tone;
- Tolerance of carrier interference, since the rotating pattern causes a rotating (spread) pattern of interference on decoding, which is easier to handle;
- Much improved robustness in NVIS propagation conditions, because signal sidebands and delayed signal elements caused by the ionosphere cannot appear on the frequency and time slot of the following signal elements;
- Very fast synchronising (sync) lock, allowing for slick operation with fast turnaround.

The improvement in robustness is so marked, that for most purposes DominoEX can be used without Forward Error Correction (FEC). This results in much higher text speeds for a given baud rate, and very low transmit-receive delays. A typing speed of 75 words per minute is achieved in a bandwidth of about 200 Hz.

DominoEX also deploys an unusual variable-length character coding system (Varicode). This is based not on the usual binary techniques, but on 'nibbles'; four-bit entities. This technique provides a good match to the transmission, which can send four bits on each signal element, and the FEC system, which uses a 4-bit interleaver. The Nibble Varicode is very efficient, with a robust character sync system built into the character set. For the first time ever in a digital mode, a dedicated 'secondary text' character set is also provided, which allows for automatic and continuous transmission identification. Whenever the keyboard is momentarily idle, secondary text is transmitted. The feature can also be used to send net control, schedule and other useful information. The text is automatically displayed in a separate window at the receiver.

The display tools provided with the DominoEX software by Con Wassilieff ZL2AFP make tuning very simple. The 'waterfall display' is synchronous with the receiver. This is also a new development, and provides much clearer and more sensitive information than other similar displays. The waterfall and other graphics allow the user to assess very easily the effects of multi-path propagation on reception. The mode is as sensitive as PSK31, but faster and much more robust, even without FEC. Synchronization is not lost on the weakest signals, which can still be clearly seen in the tuning display, which is not the case with many other modes.

The DominoEX development was designed to provide an easy to use, high performance mode for low HF bands (notably 80m), which would be appropriate for newcomers to digital modes, yet be satisfying to the expert operators. It was also intended to provide a digital mode appropriate for low power, field communications for volunteer emergency communications agencies. It has since been found to be as good as or better than MFSK16 for long path DX, and to be useful on UHF satellite communications, since it is resistant to satellite Doppler frequency shift. An error-correcting ARQ version has been discussed.

DominoEX was researched, developed and designed by Murray Greenman ZL1BPU. Software for the PC and sound card is available free from Con Wassilieff ZL2AFP, who first implemented the necessary software techniques. The mode is also available in MultiPSK by Patrick Lindecker F6CTE, who first implemented the specified FEC for added performance. A LINUX[®] version is under-way, and in the next year it is hoped that other mainstream Digital Mode software will also offer DominoEX.

Digital Radio Mondiale (DRM)

Digital Radio Mondiale (DRM) is the latest technical direction being taken by commercial broadcasting on short wave and medium wave. While DRM requires high power and transmitters with very high linearity, it offers impressive reception capabilities. It has low distortion, wide bandwidth stereo sound without the usual HF broadcasting problems of selective fading, noise, distortion and adjacent channel heterodynes.

DRM can also be used on the Amateur bands, and various Amateurs in New Zealand have recently explored techniques for its deployment. Using a special digital quadrature phasing technique, Grant Taylor ZL1WTT has built two 80 m exciters capable of generating full specification 10 kHz bandwidth DRM signals.

The software used to generate the transmission is DRM Dream by Volker Fischer and Alexander Kurpiers. Receiving software was also DRM Dream, using a communications receiver with a 12 kHz IF adaptor. Successful ground wave and NVIS tests have been carried out with a power of 5 W. The challenge now is to increase the power level to achieve improved signal to noise ratios and continue to achieve the very low transmitter distortion.

Software Defined Radio (SDR)

Software Defined Radio (SDR) techniques and processes have begun to influence thinking in new receiver and transmitter design. DRM and the use of digital techniques for phasing type transmitters have already been mentioned. These digital techniques also apply to receivers, with new designs based on Quadrature Synchronous Detection and 'In Phase' and 'Quadrature Phase' demodulation techniques now appearing. Receiver software from several sources for AM, FM, SSB and other modes takes advantage of these techniques. With a software radio, upgrades in most receiver and transmitter parameters, such as filter performance, noise reduction and addition of new modes, can be accomplished by simply changing the software.

Contact Person

The contact person in NZART for "Digital Modes" is Murray Greenman CSc, ZL1BPU. Email contact is available via zl1bpu@nzart.org.nz.

Recommendations

That:

1. Member Societies note that "Digital Modes" are increasing in popularity in Region 3, and that New Zealand continues to be at the forefront of Digital Mode development.
2. The digital portions of the Amateur bands continue to be plagued, however, with unnecessary interference. Societies are requested to publicise the development of digital modes and to educate amateurs not to interfere with digital transmissions of amateur origin.
3. To note that while PSK31 continues to be widely used, newer modes with better performance in specific areas are increasingly being used. DominoEX, in particular, is creating much interest since it has many benefits for beginners and experts alike.
4. Experiments with advanced digital modulation techniques continue, and the software defined radio is beginning to influence new designs and techniques.