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Memo:

Radio Propagation studies using radio beacons in 2004 and going forward.

Radio beacons, transmitters with some form of identification have been part of the evolution of radio since the early 1900's. Most of our known radio propagation modes have been studied and exploited based on work done with beacon signals. Beacon technology has evolved to some degree over the years but the majority of radio beacons are still based on concepts that were in place and well understood over 60 years ago.

The yet undiscovered radio propagation modes are hidden in at least a second order of smallness – it now appears that the more simple to understand propagation modes are by now well understood. We now must have new tools and techniques to identify propagation modes that are not yet understood or identified by identifiable characteristics.

Radio beacons from the research perspective have two basic functions. The first type is to assist the users in exploiting some form of propagation that is known to exist and the goal is to identify when the desired conditions exist and to then as amateurs make contacts using the information provided by the beacons.

The second basic function of a radio beacon in the investigation of propagation phenomena is to use the beacon to find a new propagation medium or to detect when existing propagation mediums might exist that could be exploited to make a rather difficult contact using new techniques. The Brendan Trophies, the holy grail of radio propagation experiments, to be awarded for the first contact over the North Atlantic on 144 MHz are an example of a challenge that will need new things done new ways to make it happen.

[Side bar below on the Brendan Trophies as offered by the Irish Radio Transmitter Society]

Simple radio beacons, cw callsign and not much else, have been in place for North Atlantic testing for the last 50 or more years. There have been less than a handful of serious reports on hearing 144 MHz signals over the North Atlantic. These reports have demonstrated that the events occur so seldom that exploiting the event has so far not been possible. The days of amateurs sitting for hundreds and thousands of hours with the headphones on are not going to happen any more.

My work on this area began in 2001 after the completion of a TransAtlantic contact on 136 KHz with G3AQC. I began the first studies of the issues that summer and have continued since, doing tests and studying how one might methodically approach the issue so that one could build up a knowledge base. The goal is of course to use that base and to work towards the completion of a QSO that would meet the requirements of the Brendan Trophies. After further study I have come to the conclusion that the goal is to break the barrier of getting across the North Atlantic on 144 MHz. If the resulting contact qualifies for the Brendan Trophies then well and good, but the goal is to get a signal across the North Atlantic on 144 MHz.

This is in no way a put down on the Brendan Trophies but it is a result of the LF work on 136 KHz, the goal was to have the first two way QSO from North America to Europe and this was done. There will not be another "first" QSO across the North Atlantic on LF.

The general case for radio propagation beacons is that they are built and put in service to facilitate the use by casual observers on a random chance basis. This form of beacon has been eminently successful in identifying a number of new and exciting propagation modes on both VHF and UHF – but the issue is still really detection of an event by chance.

The research into this has identified that a specialized form of radio beacon is required to find new radio propagation modes or combinations of modes such as are needed to get a 144 MHz signal across the North

Atlantic. As part of this work I have had extensive private correspondence with many workers in the field of radio propagation beacons. Part of this has been some private discussions with Joe Taylor, K1JT of WSJT fame and just lately with Bob McGwier, N4HY.

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Combined with an extensive study of existing beacons, beacon networks, and existing have provided me with a great deal of material – there thoughtful and kind suggestions have resulted now in the recognition of a general direction and the technologies that will be needed to exploit this initial work.

This discussion is limited to radio beacons that are designed to find and or detect new modes of radio propagation which may be composed of multiple expressions or forms of known radio propagation.

The first realization is that a radio beacon in this project must be continuous carrier - no off air time. There is one absolute certainty that if there is no beacon transmission going on then there will be signal available to be used to detect some form of propagation anomaly. This is the same as it is impossible to win a lottery if one does not by a ticket.

The second realization is that the skill level of amateurs no longer justifies the use of CW aka Morse Code as the means to identify the beacon. The identification of the station must be reduced to the identification of not more than two bits of information even hours or days apart that identifies the station with a very high degree of probability.

The third requirement is that very accurate time, from the GPS satellite system, is essential to optimizing signal detection. Very high confidence in the identification of a signal can be had if one knows at what time the signal should change state. For instance one could change state on the zeroth second and another station could change on the 5th second of the minute.

The fourth requirement has three components. The receiving system must be able to reliably detect signals that are exceedingly weak over the bit interval chosen for the experiment. Secondly the receiver needs to reliably detect signals that are only present for a very short period of time, bursts of signal. Third the receiving system needs to reliably detect signals that have been mauled by some propagation phenomena and are spread over a relatively small range of frequencies.

The fifth requirement is that the receiving system has to reliably and continuously discard 99.9% to 99.9999% of the collected data without human intervention. The inverse of this is that the receiving system has to ring the big bell only when events that have a very high probability of delivering real value to the experimenter occur. This is the real key human event issue of any system that will find a way across the North Atlantic – failure in this area, to many false alarms will most certainly result in the edict from the other half to “turn it off”.

Once this set of requirements was identified, the next need is to identify what a protocol or process might look like to implement such a beacon system. The very first essential recognition I offer is that the receiving system hardware has to be relatively cheap and commonly available. We need to make use of regular type of radios and computers, no special boxes must be needed.

The transmitters can be a little different, and the continuous carrier operation mode will task our peers to build new high reliability amplifiers. We need a lot of receiving systems we only need a few transmitters for the 144 MHz North Atlantic challenge.

My next step was to take some immediate decisions on the transmitting protocol. The first requirement is that the transmitter must operate in a nonlinear mode, or stated more accurately to the requirement the transmitter must not demand operation in a linear mode. Next there is a need to recognize that the radios available for reception do not have super accurate frequency calibration but that in general once they are on a frequency they manage to stay substantially in the same place.

A study was made of the WSJT family of protocols. The FSK441 system makes use of only four discrete tones. Another option was to use a tone per character, as the JT44 family of protocols does. This was discarded as requiring greater receiver stability than might be commonly available in the general amateur community at this time. The four tone option was studied further and a simple relationship was found. If the four tones were chosen carefully the reception of any two of the four tones, even many hours or days apart could identify the beacon station to a very high degree.

For instance, please review the following. If one transmitter four tones F1 to F4 as follows…

F1 28170.792
F2 28171.080
F3 28171.440
F4 28171.872

The reception of any two of these tones will uniquely identify the sending station. See as follows

F1-F2 288 Hz
F2-F3 360 Hz
F3-F4 432 Hz
F1-F3 648 Hz
F2-F4 792 Hz
F1-F4 1080 Hz

The reception of a signal, either weak continuous, burst, or smeared signal (but smeared in a balanced process around the center frequency) can uniquely identify the transmitting station – just as good as copying a cw call sign. I hope to make the case here in Canada with our regulatory officials so that a time slot is not needed every half hour to send a cw identification.

There are many other combinations that can be used, and different beacon stations should use unique sets of tones so that they can be uniquely identified with the reception of just two bits of information.

For this work I propose we use a four tone protocol, this has 64 discrete tone patterns when three of the four tones are used per character. If one only uses three tones the discrete tone sets are limited to 27 discrete tone sets which is not adequate for the Roman alphabet and the set of numerals zero to nine. The four tone protocol also allows the identification of single event message codes, such as “000” or “111” or “222” or “333” to mean a specific function, such as using “333” to mean “change protocol” from a beacon mode to a protocol that would perform a two way QSO function. In the particular tone plan proposed here, if one detects a “3” in bit position 1, 4, 7, 10, 13 and so on is also unique and can be used as a message code as well.

The basic bit element I propose for this work is One minute per bit. The start time of the bit is also selectable, see above in the requirements discussion.

The minimum distance between F1-F2 of 288 Hz is by test adequate to support exclusive identification of the transmitted bit in both burst and spectral broadening propagation modes. I have been able to make extensive use of the Ottawa Amateur Radio Club ten meter beacon on 28175 KHz for some years. The path to my current home is some 75 miles and I observe the beacon for some years. In fact I built the first version of this beacon just over thirty years ago – going for FSK operation back then was a huge stretch and we had to deal with many complaints from those who could not deal with copying a CW identification on an FSK system. I observe airplane reflections, meteor pings, auroral reflections, and some times there are reflections that I do not understand what they are caused by.

The four tones can be observed with any of the many popular DSP computer soundcard programs. I have had an early prototype running a few milliwatts running for some time. As this is written I have been digging in my junk box for the bits and pieces to put a test beacon signal on the air using this four tone

protocol as soon as possible. The goal is to put a reasonable signal on ten meters for the 2004/2005 winter so that the receiving system can be developed. The power output will be in the order of 10) watts or so.

Once a mature receiving system is in place, and the offered protocol in this memo has been accepted, modified to make it better or replaced by a more advanced design - the next steps can begin. The goal of this memo is to begin the methodical approach to the task of achieving a QSO across the North Atlantic on 144 MHz.

This memo seeks to identify the components and process needed to begin a focused approach to identifying and documenting radio propagation events that might occur in a given radio circuit. The method uses a dedicated radio beacon with characteristics that will facilitate the machine reception of the signal. Once signal events are detected the collected information can be used as a basis for an automated digital radio process that can be used to achieve a two way contact over the North Atlantic on 144 MHz. This memo represents the conclusions of a multi year investigation into the issues that need to be involved. The work makes use of information gathered from every source I could find, private discussions and correspondence, and as noted earlier discussions with Joe Taylor, K1JT and Bob McGwier, N4HY. These men so graciously let me ramble on and on and I am sure they will say and on and on and on etc.

I am open to discussion and debate on this memo.

Larry Kayser
VA3LK / WA3ZIA
VA3LK@RAC.CA

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