

Communication using WSJT, JT65 "Deep Search"

This article provides a brief description of K1JT's concept "Deep Search", which is a software module created in the interest of minimizing the transferred information during a digital QSO, using database comparisons and recognitions to identify the stations involved. The way the program works is not known to most people and therefore an explanation is needed. Despite the fact that this software was developed primarily for VHF/UHF-traffic, there is some reason for every radio amateur to ponder over digital concepts, where as little information as possible is transferred via the radio path. There is, therefore, a great risk that over time this will devalue the achievement of making QSO's . Furthermore, it creates an imbalance when comparing achievements for awards, toplists or in contests. This is analyzed at the end of the article, where we also take a look at how future software solutions for digital communications could affect ham radio as a hobby.

For a number of years Joe Taylor, K1JT has developed his software (WSJT), mainly targeted for "weak signal communication on VHF/UHF". This concept is based on frequency shift keying. The program consists of a number of different modules, each one optimized for different types of communications (meteor scatter/EME/tropo). The program is ready to use after connection the computer via the sound card to the radio.

FSK441 is probably the most widely used program for meteorscatter on both 144MHz and 432MHz, while module JT6M is optimised for use on 50 MHz. Both use a digital protocol that in principle are character based, i.e. every character is sent and decoded separately. Any short message can be typed into the program and it is transmitted and decoded in it's original format.

The program has another module "JT65", which is primarily for EME or tropo communications. The JT65 module is designed in a different way from the JT6M/FSK441 program as the coding of transferred data is based on symbols rather than characters. This concept leads to limitations as to what can be sent and decoded. Decoding in JT65 is also done differently depending on the S/N level of the received signal. This is where the software differs distinctly from all other communications protocols that we are used to.

The purpose of this article, as explained above, is to try to explain parts of the functionality in JT65, but also at the same time highlight what I and many others in the EME community see as a problem with this type of software. There are actually a number of options in the program that are designed to ensure that as little as possible of the information in a QSO is received via the radio path. This makes the JT65 module both unique and controversial. The amount of received data diminishes drastically as the S/N level goes down. At the level where most EME QSO's between small stations take place, only fractions of the full message is received. The processor is instead using known data, available on the computers harddrive or memory to compare with the fragments received via the radio. The computer is then doing a qualified guess as to what the message is, i.e. what callsigns are involved and it then prints the full message on the computer screen.

This is what the inventor, K1JT calls "Deep Search". This, however, is nothing like a deep search in the radio noise as the name implies, but instead it is a qualified guess. Of course, this has no resemblance to a traditional CW/SSB QSO where the operator via the radio copies a message from the other station and acts upon what is being heard and decoded. Traditional

contacts don't have the limitations of this digital protocol either, as you can send anything in CW/SSB and it will be received as it was sent.

As we see, in JT65 things are different. The software has significant limitations because the Deep Search module can never decode unknown callsigns or locators. Everything must be known in advance and presented to the CPU. The Deep Search decoder is looking for fragments of the 72 bit long message that the other station is transmitting to compare with the known data already present on the computer. When there is a probability of a match to these received fragments, the calls and a locator is printed in full on the computer screen. During this Deep Search process, the computer may not even have copied half of one callsign to perform the guessing. Two complete calls are at least 56 bits long, but in Deep Search 14 bits or less are required to produce full calls on the screen. This means that 25% or less of the original message is actually required to be received via the radio. The operator is unaware of this and is lead to believe that all information has been recieved.

- **Why do I and many others care about this and what does it mean to EME or tropo QSO that are made?**

Well, the controversy is based on the fact that for these type of contacts there is a commonly agreed QSO protocol, established long time ago. And every contest, award or toplist relies on the fact that this protocol is used, so it is in effect the foundation that all these acievements are built on. The procedure is indeed similar to the one defined by the IARU Region 1 for meteorscatter, which is widely accepted among the VHF/UHF community.

The definition of a minimum valid QSO is that both stations have copied all of the following:

- 1. Both callsigns from the other station**
- 2. Signal report from the other station**
- 3. R from the other station, to acknowledge complete copy of 1 and 2.**

This has been the standard definition of a minimum EME QSO for many years.

(ref. http://www.nitehawk.com/rasmit/g3sek_op_proc.pdf)

So, we are supposed to transfer both calls in full, a report and an acknowledgement that these messages are received in their entirety.

As we can see, the Deep Search module will never fulfill the requirements. Actually, the module is not capable of communicating full callsigns. It is, instead, working with a minimum of data transfer to do it's guessing. At the S/N level where Deep Search is activated, it is impossible to transfer more than one callsign in a 60 second period. This is due to the coding scheme. The operator who uses JT65 Deep Search is, however, lead to believe that two full calls, a locator and a report can be transferred in 48 seconds (normal TX/RX periods)! This sounds like a miracle for sure, but the true story is that the major part of the message is never actually received.

In reality, this means that the only "Deep Search" that is being done is on the harddrive of the computer and not in the radio noise as most JT65 users are lead to believe.

- **So, we ask ourselves, how can the program find the correct calls so often?**

The answer is quite simple. It is because there are so few EME hams in the database (CALL3.txt). If the database contained more calls, we would, after a while, reach the level where the Deep Search module would always produce false calls after its guessing procedure. This is mathematically proven and described in an article by DJ5HG, published in Dubus Magazine (<http://dubus.ns.km1708.keymachine.de/dj5hgds.pdf>).

But the program has other options to make the guessing process more confident. If you type the callsign of the other station into the "To Radio:" box, the program will make use of this information and compare it with the fragments already received. The probability of a "hit" is quite high as the operator has already indicated part of the information that should be printed in the screen. The operator can also activate an "Agressive Decode" option to lower the threshold even further and allow guessing at lower confidence levels.

The need to know the other stations call and locator has resulted in the creation of a number of chat pages on the Internet, called "Loggers". This is where JT65 operators find sked partners in real time and exchange the required information about calls and locators to present to the software. Self spotting on the DX-cluster is also used extensively, all in the interest of doing away with the unknown callsigns and locators, which are strong limiting factors to weak signal digital EME.

So, these are the reasons for the reported success with EME when using JT65 Deep Search, which is contrary to common belief that the software is able to dig deep into the radio noise and decode messages. And, not to forget, if we fill up the database with more calls, the software will never guess correctly.

- **Why did K1JT create the so called Deep Search module then?**

We can only speculate, but in short, it was probably because he was not able to launch a whole new software concept, called JT1 (JT One). This concept was marketed at the EME conference in Trenton in 2004, and it was said to be able to detect and decode signals many decibels lower in S/N than JT65.

Furthermore, Joe Taylor was going to do away with the "Shorthand Message System" he created to minimize the signal report and acknowledgement to 2 bits only. Apparently, he had taken notice of the criticism against these Shorthand Messages, which were easily triggered by noise or spurious carriers and he therefore set out to create a "more robust" report system.

Unfortunately he was not able to complete the JT1 project. Difficulties with the EME signals and chosen techniques made it impossible for him to achieve what was promised.

When JT1 failed, Joe Taylor instead launched the Deep Search module in JT65. The claim was that by doing so he had introduced "4-6dB more sensitivity" in his software. Of course, this was not true and as we have seen above, the new concept was designed to minimize data transfer in respect to the full EME message. On the surface, it looked like better sensitivity was being achieved, but we now know better.

Shorthand Messages were left intact and still contain no information. They are just two tones spaced differently apart to represent RO, RRR or 73. Many operators just look for the tone

spacing by looking at traces on a waterfall display to determine if a QSO is complete. There is no challenge in "copying" the report anymore and a QSO that has come this far virtually never fails.

Another option that turned up in the JT65 software was the ability to add an extra DXCC prefix to the internal database. As JT65 is limited to a certain amount of "valid" callsigns, there have been a number occasions when, for example, DX-expeditions have not been able to transfer their prefixes. To solve this problem, the possibility of adding additional prefix's was incorporated. For example, "PJ4". If both operators add this prefix, a callsign like PJ4/PA3CNX will be displayed on the PC screen correctly. But, in the underlying protocol there is just a flag being sent that states that an extra DXCC prefix is activated. There is never any decode of this prefix and PJ4 is never actually transmitted.

So, one operator might have entered "PJ4" as an extra prefix and the other one "ZK2". The software at either side will display "PJ4/PA3CNX" or "ZK2/PA3CNX" depending on what they have entered. As with Deep Search, this concept is based on the fact that the full message is never transferred and for a QSO to be valid, the correct prefix must be added in advance. But again, it really doesn't matter what you enter, because it is never transmitted or decoded.

Early versions of JT65 Deep Search presented the operator with a multitude of so called "decoded" EME messages. If the program was left monitoring noise, it was prone to fill the screen with QSO information or stations calling CQ. You could, on occasions, even find yourself having a QSO and this, of course, took things to a laughable level. But in reality, there are a few hams out there who have received QSL's for contacts that were nothing but computer generated trash. All the "information" had emanated from the database (CALL3.txt) that was distributed with the software.

Over time, many of these false decodes have been successfully suppressed by changes to later versions of the program and are not seen quite so frequently. However, there were operators who expressed concern with Deep Search and the fact that they had no control over what was actually "received" or displayed. Many prominent operators who were seduced by the mode claimed that they never use Deep Search because, at K1JT's suggestion, they had emptied the database on their harddisk. Well, nothing could be further from the truth because as soon as a call is entered into the "To Radio:" box, the Deep Search decoder uses this known information in the "guessing" process. In all versions, except for the very recent one, Deep Search could not be switched off.

Minimal QSO's

As we now understand, there is no way to compare the achievements of a JT65 Deep Search QSO with one made in either CW or SSB, where the operator decodes the information, in full. This is where my opinion differs from the JT65 Deep Search users and I have many supporters. It is our opinion that by accepting Deep Search QSO's in contests, for awards and toplists we are undermining the integrity of a QSO and doing our radio hobby a bad service. The achievement with Deep Search is more in the guessing algorithm than in the ability of the operator and his radio station.

Unfortunately, as so few amateurs have questioned what the software is actually doing, or even possess the knowledge to understand, contacts made using Deep Search are presently fully compatible with CW/SSB QSO's for the DXCC award. The ARRL has for many years

accepted digital communications in the form of JT65 in the same category as CW/SSB, without thinking about the consequences.

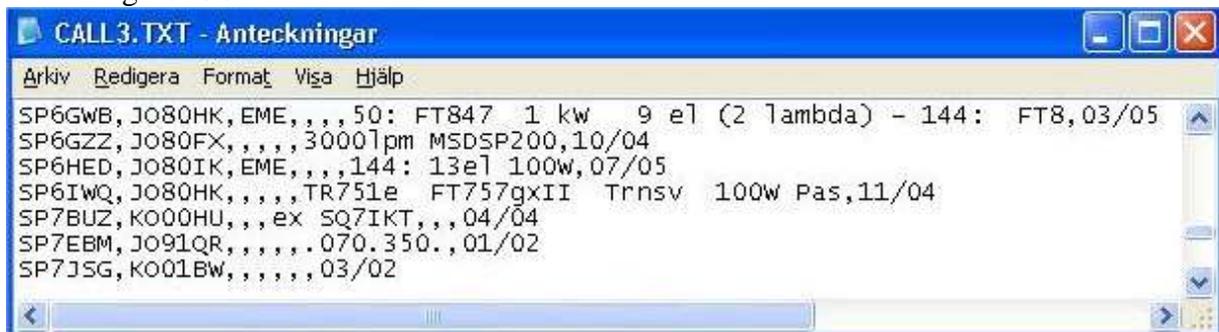
Fortunately, there are organizations and award/toplist sponsors that don't accept Deep Search contacts at this time. They have come to the conclusion that the "achievement" bears no comparison to QSO's made on the more traditional modes.

People then ask, in all fairness, why this is so controversial and important to discuss? Using some examples, I will present the functionality of Deep Search, but also point to some minimal QSO concepts that will explain what path we are on when choosing this concept.

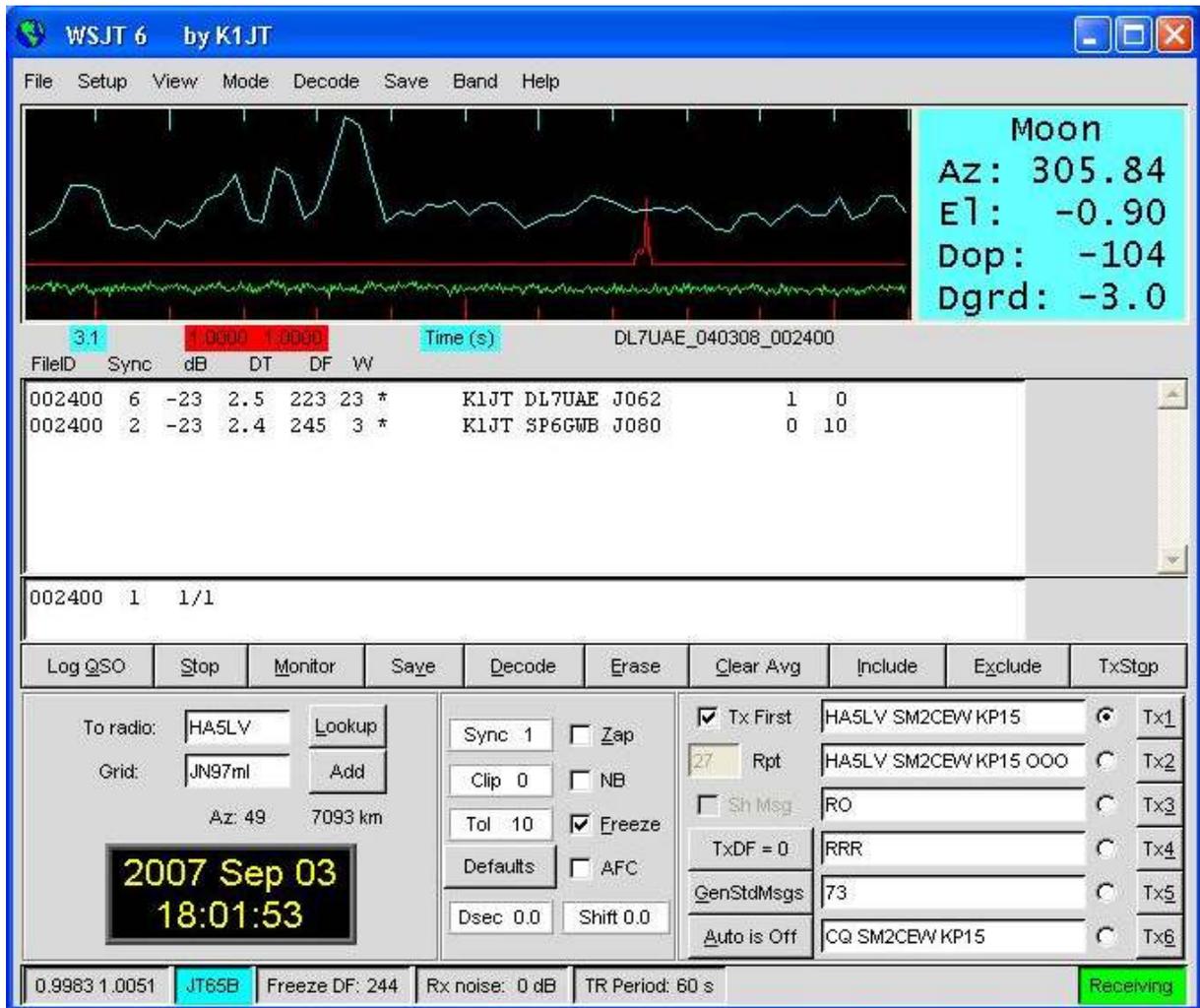
The Deep Search Database

With a aid of a few pictures, I will illustrate how Deep Search works and how the database entries are being used to produce and display the text that the software is claiming to have received via the radio path. To help, I have downloaded the tutorial files from the WSJT homepage. These files are produced and recorded on EME by K1JT himself. When performing these tests, I have installed them and used them as per the instructions on the webpage. The software has also been set up in accordance with the tutorial. The latest version of WSJT is used (ver 5.9.7).

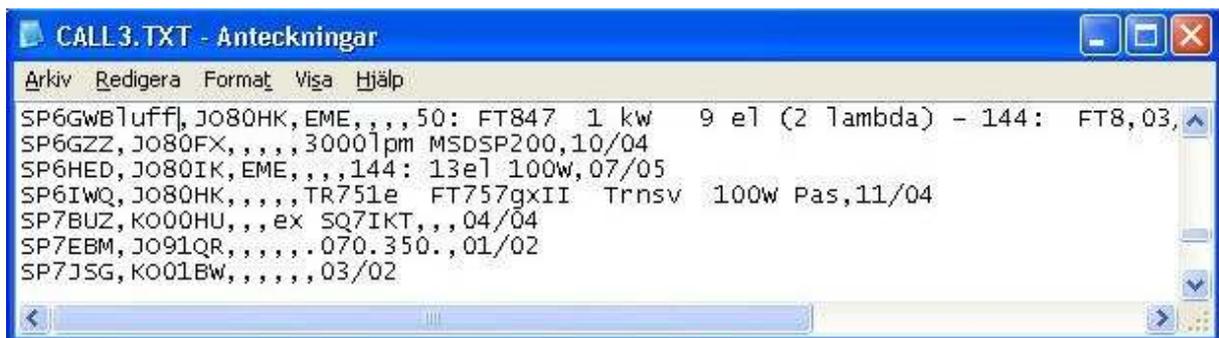
The first picture shows a decode of two stations in the same file, representing a "QSO" between K1JT and DL7UA and SP6GWB respectively. Both stations callsigns and locators are to be found in the database (CALL3.txt) that comes with the program. Below we can see the callsign SP6GWB on the first row of the database extract.



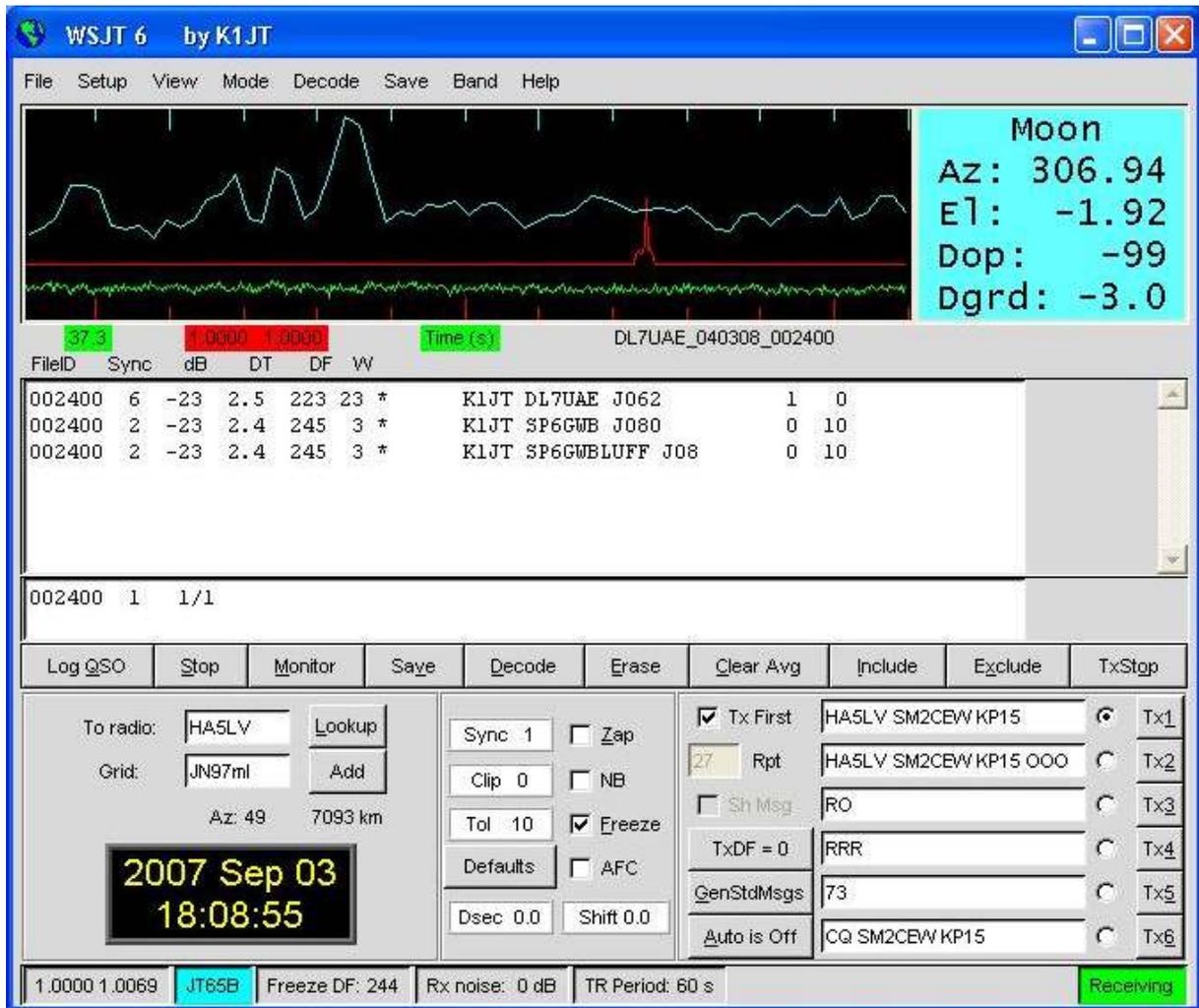
The software is decoding the message as following, and we recognize SP6GWB and the locator JO80 from the database.



Now we edit the database entry by changing SP6GWB to SP6GWBluff to see what the software will decode (see the database info below).



This is a decode of the same file as before (the last line of the text window)



The software is producing a totally false callsign, based entirely on the information stored in the database. This decode is possible with an authentic recording of a JT65 Deep Search EME QSO, made in the shack of K1JT. We can clearly understand that it's not the radio signals the software is decoding. It's more about using data on the harddisk and making a guess..

Minimize further..

It becomes obvious that if someone wants to develop a software concept that will perform better than Deep Search, they have to minimize the data transfer even further. We could then end up at a level where the amount of data transferred is equal to receiving one character or less in a callsign. In accordance with the fact that a Deep Search QSO today qualifies for DXCC, awards and toplist, a single letter transfer (or less) should also qualify for these awards. Denying this would also be a denial of Deep Search.

We should not fool ourselves into believing that this scenario is fiction. What is already discussed is to book a digital symbol via a real time Internet booking service that represents a personal callsign. The operator at the other end will book another symbol and these are transferred via the radio path for the QSO to be completed.

Surely, such a limited transfer of data can never fail, but is it a QSO? What is the difference between a Deep Search transfer of 10 bits or transferring a booked symbol of say 4 bits according to the concept just described? In these two cases, not even one full callsign is transferred, so we can hardly reject the 4 bit transfer and not call it a valid QSO if we gladly accept Deep Search! Where do we draw the line?

A strong supporter of WSJT, VK7MO created a procedure for transferring single letter calls with the WSJT program. This is an example of one of his tables:

Call Sign codes:
A = Andrew VK5ZUC
B = Ray VK4BLK
C = Charlie VK3FMD
D = Dale VK5DC
E = Jim VK3AEF
F = Rex VK3OF
G = Ron VK5AKJ
H = Dave VK2AWD

I'm sure that the majority of the amateur community will agree with me when I say that this is not a particularly interesting perspective for the future development of our hobby. But this is already a reality. As we can see, it is all about minimizing the the need for a radio link to succeed. But in my eyes, the radio link is the basic foundation of our hobby and I know that I am not alone in this belief. We can have QSO's by using CW, SSB, RTTY, PSK31 or any other mode, but the radio path should be the carrier of the information. When doing so, people can listen when the propagation allows. And the fact that people can listen promotes an understanding of what is happening, possibly encouraging them to make QSO's or to develop improvemens in their own station. This is precisely what is so appealing to VHF'ers and DX'ers.

- **Will someone be able to monitor a QSO between two stations when signals in the monitoring receiver are at the S/N level where the Deep Search module is activated?**

The answer is NO, not without taking certain actions. To get a decode (qualified guessing) both callsigns and the locator must be correctly typed into the software, by the operator. That is, one of the callsigns need to be entered as "My Call". Without this input there will not be any decodes. If part of the QSO information is unknown, the monitoring station will not decode anything. Of course, hanging out on Internet loggers, providing the computer with all information in advance, is essential, even for monitoring.

- **Is everything about JT65 bad?**

Of course not! There are many interesting and smart solutions for digital communications within the software. It is very popular and has created a lot of activity on frequencies where it used to rather quiet a few years back.

And when signal levels are such that a CW operator still manages to to make a QSO, a totally different module is doing the decode in JT65. It is called the KV-module (Koetter-Vardy) and is using the overhead information of the 72 bits message to recreate missing data. The KV-module either fails completely to decode or prints a 100% correct message on the computer

screen. Then again, we are now talking about signal levels where the operator can hear the FSK tones in the loudspeaker or the headphones, so it is hardly any digging into the noise.

JT65 has recently become very popular on the HF bands, where it is mainly the KV-module that is doing the decode. The problems with dependence on a database does not exist in the same way on HF as on VHF/UHF EME.

The Future

All of you who have followed me thus far understand that the criticism of Deep Search is all about how we characterise and determine a radio QSO. And then primarily for EME, where a well defined procedure that clearly states what needs to be transferred and received for the QSO to be called valid.

But this article is also about discussing with a larger group of radio amateurs whether we should call a digital exchange where not even one callsign is transferred a full QSO? In the case of Deep Search we are talking about a transfer of the equivalent of two characters, so why can't we draw the line at half a character to constitute a full and valid digital QSO?

The fact that no other radio amateur can listen to this QSO and understand what is going on because he is not in possession of the code table should not matter, should it? The QSL card will eventually show what went down, when the DXCC Field checker gets it for approval.

We appreciate that all of the historical achievements, like tropo distance records or DXCC awards that were made using CW/SSB are indeed impossible to compare to the ones made using digital modes, such as JT65. The fact that Deep Search QSO's presently have the same status as traditional modes for DXCC is something that I find totally ridiculous. The amount of DXCC awards issued on 144 MHz have "exploded" since the launching of Deep Search. This is of course nice for the operators who have been wanting such an award, but they cannot be compared to earlier achievements, using traditional modes.

Recognizing these differences and separating them into different categories is indeed justified. But more important is to consider a better definition of what constitutes a digital QSO! Increasingly, it appears to be NOT about an RF radio contact, which in my view a bad thing for our hobby. I like radio communication and I feel that our QSO's should be made via the radio waves. If we continue to allow the computer to decide how little information is received and guesses what is missing, doing away with the operator, we are heading the wrong way. It should be about skill, judgement and personal integrity.

This leads us into a spiral where code tables or databases will be mandatory to make a QSO, instead of callsigns and reports. And the monitoring stations need to be logged on to the relevant database, else they stand no chance of understanding what is going on.

We are really close to this with the Deep Search concept. The only difference is that the database is distributed with the software and is stored on the harddisk of the computer, rather than just available on the Internet.

Of course, we should continue to develop new software solutions and let new thoughts and ideas flourish of how to make use of the computer to dig for weak signals in the noise. I would really like to try the software that can dig out two completely unknown callsigns and a report at S/N -27 or lower, almost in real time!

Because so far, no amateur software is able to do it, regardless if the inventor of JT65 says his software can. But that's only marketing and nothing else!

73 de Peter SM2CEW