Deep Search Cannot Communicate Callsigns

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There has been some discussion on the validity of QSOs which use the deep search decoder of JT65 [1,2,3,4]. The goal of this paper is to explain the basic principle of deep search more intuitively, but without loss of correctness.

1. Discussion of a Specific Situation

We first analyse the situation shown in figure 1: My neighbour's LCD-TV radiates into my EME-array. The noise seems to be white but it has a slight signature depending on the program he looks at. The noise is fed to the left channel of my sound card. A second receiver for 144 MHz directly takes the noise from my own TV and feeds it to the right channel of the sound card. My computer correlates both channels, i.e. it computes a measure of the similarity of both audio channels. This value is displayed at the correlator, one at a time. If I now scan all the TV programs, I get a corresponding set of similarity values. One of these values will be significantly greater than all others. Therefore I am very confident having found the program my neighbour looks at.

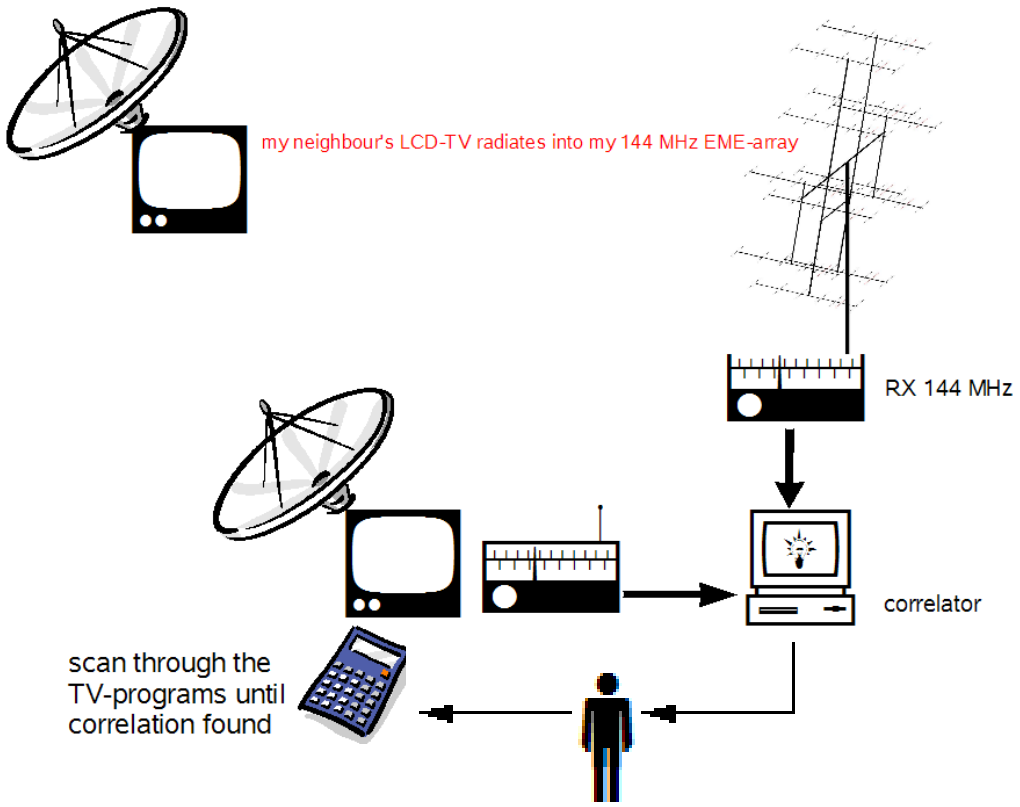

Figure 1. My neighbour's LCD-TV radiates into my EME-array. The noise seems to be white but it has a slight signature depending on the program he looks at. The noise is fed to the left channel of my sound card. A second receiver for 144 MHz directly takes the noise from my own TV and feeds it to the right channel of the sound card. If I now scan all the TV programs, the correlator will measure the similarity of both signals, one at a time. After the scan I choose the TV program that produced the maximum value of similarity. The information flow is indicated by arrows. Please note that information from my EME antenna to my TV screen only flows via my brain and my infrared remote control.

Now I switch to the program my neighbour probably looks at. This corresponds to the action of displaying the result of the decoder. Where does the information that is displayed on my TV screen come from? Which way does it go? It clearly comes via my TV dish. But, what comes via my EME antenna? Indeed, what I see on the TV screen fully depends on the signal received on 144 MHz! Obviously there are two different informations: (1) the information coming from the satellite dish which leads to the actual scene on the TV screen, and (2) the information which program to choose. Note that the latter information flows via the infrared remote control. There is no other way from my EME antenna to my TV screen.

The amount of information that must be received via the 144 MHz channel to get the right TV channel depends on the number of channels to check. Mathematically it is the base-2-logarithm of the number of channels, i.e. 2, 3, 4, 5, 6, 7, 8 bits for 4, 8, 16, 32, 64, 128, 256 channels, respectively. So, in the case of 64 different TV programs to check we must receive 6 bits of information to make a confident choice between all these programs. This information has nothing in common with the actual scene on the TV screen.

2. The Case of Deep Search in JT65

To get the case of the deep search decoder, we have to replace four details of figure 1: (1) my satellite dish by the call3.txt database, (2) my TV and associated 144 MHz receiver by the signal generation of JT65 and my computer screen, (3) me and my remote control by the JT65 program loop that automatically scans the possible messages generated from the database, and (4) the satellite dish and TV of my neighbour by the station calling me on 144 MHz using JT65. The general information flow remains the same. As a consequence, what I see as the decoded result on my computer screen comes from the data base, i.e. the callsigns are not received via the radio path. But the decoded result was selected out of a number of possible messages. Since this number is proportional to the length of the call3.txt database, the number of effective lines in this list is a measure of the difficulty of a QSO.

As a consequence, deep search does not comply with the classic QSO rules which demand for the reception of the callsigns via the radio path.

3. A Comparison with a Traditional Mode

CW or SSB with the alphabet „Alpha“, „Bravo“, ... are not very different. In that case the receiver does know all Morse characters and the spelled alphabet „Alpha“, ... (that is his „data base“). Receiving a message, the operator has to select the most similar character one after the other. So, the characters and decimal digits are not received. What is received is the actual choice like: the first is most similar to „Delta“, the second is most similar to „Juliet“, the third is most similar to „Five“ etc. The only difference beween deep search and the traditional modes is the number of possible choices for the complete message which, as we stated above, is a measure of difficulty. If we use 43 different characters in the Morse code we have 43 choices for each received character. Therefore, there are 43*43 and 43*43*43 different messages of two resp. tree characters. Table 1 shows the numbers of different messages for the binary case (only the two characters 0 and 1), for the CW case (43 characters), and for the JT65 case (64 characters called symbols here). It is easy to conclude from this table:

(1) A JT65 message (marked bold) contains 12 symbols of an 64-alphabet. This corresponds to a CW message of roughly 13 characters.

(2) The deep search decoder only takes into account about 4096 possible messages. This corresponds to a message of 12 bits in the binary case or to only two symbols of the original JT65 message (only 1/6 of what is sent!) or to less than three CW characters.

Table 1. Number of possible messages for the binary case (2 different symbols), the CW case (43 different symbols), and the case of JT65 (64 different symbols). JT65 uses a fixed message of 12 symbols (marked bold in the table). It's number of choices is approximately three times that of a CW message of 13 symbols. The number of possible messages decoded by the deep search decoder is about 4096 which corresponds to a message of two symbols of JT65. A CW message of three symbols already has 79507 possible outcomes, and it, therefore, transports much more information than deep search.

message length	binary case	CW	JT65
1	2	43	64
2	4	1849	**4096**
3	8	79507	262144
4	16	3418801	16777216
5	32	147008443	1073741824
6	64	6321363049	68719476736
7	128	271818611107	4398046511104
8	256	11688200277601	281474976710656
9	512	502592611936843	18014398509481984
10	1024	21611482313284249	1152921504606846976
11	2048	929293739471222707	73786976294838206464
12	4096	39959630797262576401	**4722366482869645213696**
13	8192	1718264124282290785243	302231454903657293676544

An additional feature of deep search is that it by principle cannot communicate more information by repeated transmissions. Once the program is found in the TV case of figure 1, a repetition of the search only can increase the confidence. The same is true for the JT65 deep search. Since a radio amateur cannot arbitrarily change his callsign there is only one legal message to contact a station. A repetition may increase the confidence into the decoded message, but no additional information is received.

Since a QSO with identification of the calls based on deep search usually are pursued by dual-tone short cuts, the total amout of information received at either station is less than 16 bits which is less than necessary to receive a single callsign. On the other hand, the decoding thresholds of JT65 are set such that the mutual identification based on the call3.txt list is more confident than the identification of a callsign in CW at marginal conditions. But getting „HG“ (the two characters only indicate an equivalent to 12 bits) at a confidence of 99.99% is not as good as getting „DJ5HG“ at a confidence of only 99%.

4. A proposal for the Validity-Rules of a QSO

In most sportive disciplines there are clear definitions of the difficulty of actions for example the time to sprint over a distance of 100 m. In ham radio the difficulty of a communication heavily depends on the actual channel and on the amount of information to be communicated via the channel. The simple rule to demand for the exchange of both callsigns may be sufficient for traditional modes. With the advent af advanced digital modes the minimum amount of information should be specified more precisely. The author proposes the following formulation:

A valid contact is one where both operators have
(1) mutually identified each other,
(2) received a report, and
(3) received a confirmation of (a) the successful identification and (b) the reception of the report, and – necessary at one end only - (c) the confirmation.

This formulation avoids the problematic term *copy*. Without loosing any confidence in the QSO, it also respects the fact of the large difference between the two calls that in some sense must be received (I do know my own call in advance, only the other call really is new and must be communicated). Of course, the term *identification* has to be quantified. My suggestion is:

The identification process must be based on, or equal to, a decision out of a number of equally likely possible choices that is larger than the number of licensed radio amateurs throughout the world.

This formulation by no means does restrict any future coding schemes. It simply excludes lossy source coding of callsigns, and guarantees fairness. The formulation also solves the well-known problem of the validity of skeds: The decoder must take into account all possible callsigns. If it only looks for the sked partner that renders the contact invalid.

The proposal also avoids any formulation directed to digital or analog methods. It is entirely independent from those parameters.

It should be noted that there are more than 6 billion Morse texts of 6 characters to form a callsign. That is a factor of thousand times the value demanded by the above rule. So, traditional modes like CW or SSB comply with the proposed rules. On the other hand, deep search only tries some thousand possible outcomes instead of some million. The striking difference of a factor of one million between traditional modes (and JT65 without DS) on one hand and deep search on the other hand is the reason for the indignation by some amateurs.

5. A Concluding Challenge

If there is any remaining person believing that deep search can communicate an amount of information as specified above (21 bits) please send me the algorithm **A** that encodes arbitrary 21 binary digits (or 4 upper-case characters plus decimal digits) into a JT65 message and the algorithm **B** that reconstructs these 21 bits (or 4 characters) from what is displayed on the screen by the deep search decoder. The search for these algorithm may provide you with deep insight. So it may not be waste of time although the task is proven to be impossible.

Literature

[1] P. Blair, *EME contacts using digital modes*, DUBUS 34, No 1, p.76, 2005.
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[3] J. Taylor, *How Many Bits Are Copied in a JT65 Transmission?*, DUBUS 35, No 3, pp.64-68, 2006, also printed in EME 2006 conference, Würzburg, 2006
[4] K. von der Heide, *A Comment on Joe's Paper „How Many Bits are Copied in a JT65 Transmission"*, DUBUS 35, No 4, pp. 62-64.