Comparisons of QRA64 and JT4 for 10 GHz EME

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Abstract

Our results indicate that for 10 GHz EME (spreading of 50 Hz) QRA64 has an advantage over JT4 which varies from around 1.5 dB when working in sked to around 4 dB when working an unknown or random station. Other attractive features of QRA64 are that it does not make use of a callsign database file, and is virtually immune to false decodes.

Introduction

JT4F has been used extensively for 10 and 24GHz EME for some years with very good results. In 2016, Nico Palermo, IV3NWV, designed the internal framework of a new digital mode that came to be called QRA64[1]. The mode was fleshed out and implemented in WSJT-X by Nico and Joe Taylor, K1JT[2]. Nico and Joe's initial work was aimed at VHF EME where QRA64 outperformed JT65. In July 2016, we conducted on-air tests to see if the improved performance would translate to 10 GHz EME where libration spreading is much wider than the tone spacing. Following our initial tests, which showed similar performance to JT4, Nico improved the decoder to cope with the higher amount of signal spreading with microwave EME. The results we report relate to this improved decoder as implemented in WSJT-X r7609 or later.

The short moon window between us limited the amount of time for testing, and so we investigated the use of simulators built into the WSJT-X suite to be able compare the modes. Simulation allows the use of a far greater number of test signals, to overcome the statistical uncertainty present with the much smaller sample size from on-air tests.

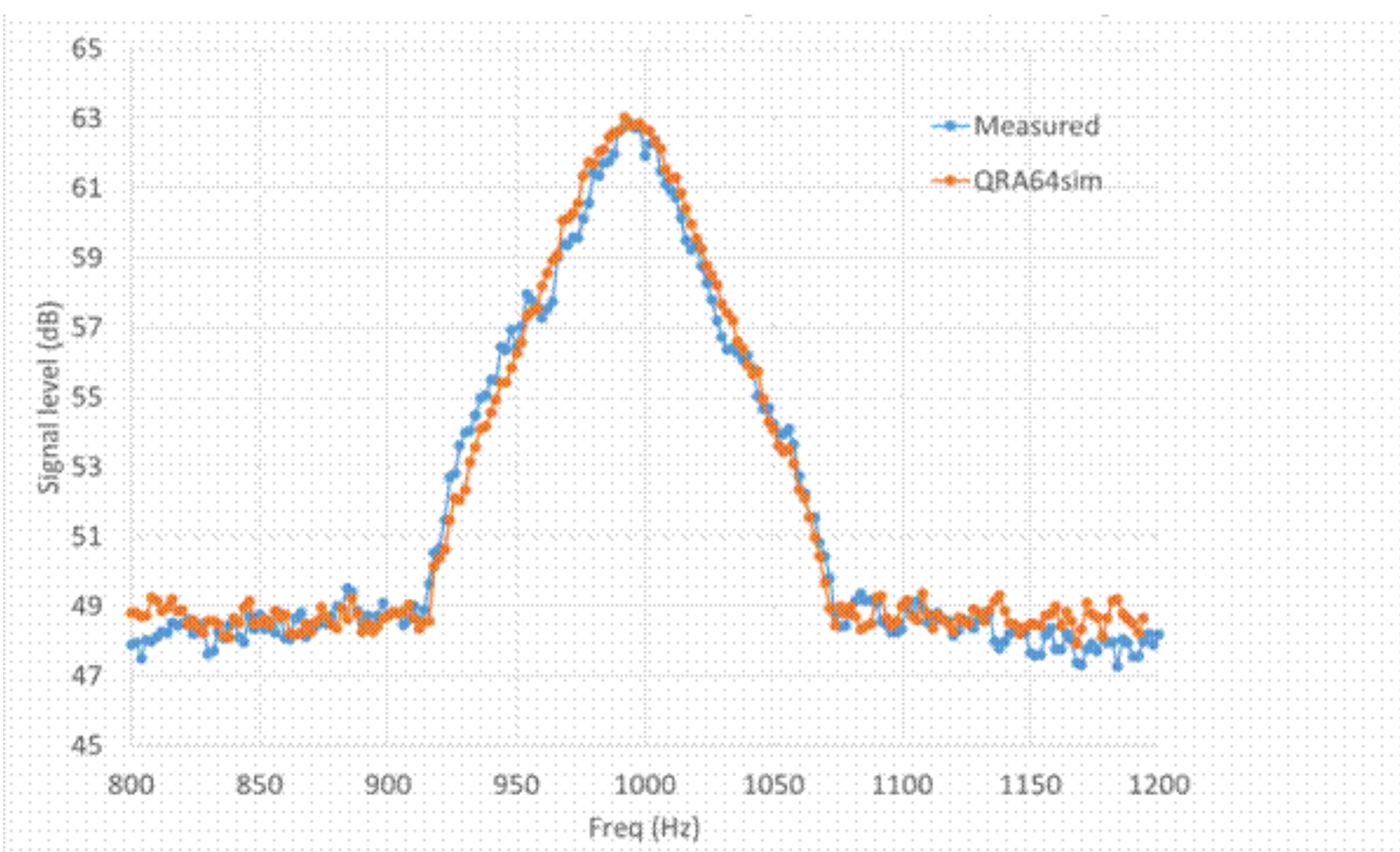
There were some known limitations in the accuracy of the simulators available at the start of this work, and K1JT made modifications to the signal spreading algorithms in the QRA simulator, so that the simulators matched our experimental measurements of signal shapes with a high degree of accuracy. The algorithms in the JT4 simulator were later changed to be identical to those used in the QRA64 simulator. The modified simulators were then able to be used with confidence.

QRA64 and JT4

QRA64 does not make use of a Call3.txt data base (as does JT4 when using Deep Search) but instead uses information gained from previous successful decodes as a QSO proceeds. For example as we know our own callsign this can be used to improve decoding of a message that is directed to us and a further improvement can be gained once we have decoded the other station's callsign to decode the report.

Simulation Method

Libration spreading (which can be up to 200 Hz or more at 10 GHz) arises from the different Doppler values of reflections across the face of the Moon and increases in proportion to frequency. In addition the shape of the spreading varies with frequency, such that at VHF the spreading tends to have a narrow central peak due to specular reflection from what VHF sees as a relatively smooth surface. At the shorter wavelength of 10 GHz the Moon appears rough and gives a more diffuse reflection with the reflected energy spread more evenly across the face of the Moon. Accordingly, it is necessary to apply a spreading algorithm that relates to the wavelength we are attempting to simulate. Graph 1 shows an example of the performance of the simulator compared to on-air measurements with a single tone.



Graph 1: Shape of simulator and on-air results obtained between G3WDG (3 metre dish) and LX1DB (3 metre dish) with 154 Hz spreading.

Our simulations are based on 1000 tests at 0.5 dB increments and linear interpolation between dB levels to determine the 50% decoding level. We estimate that by using 1000 tests the result is good to 0.1 dB.

Performance improvement of QRA64 compared to JT4

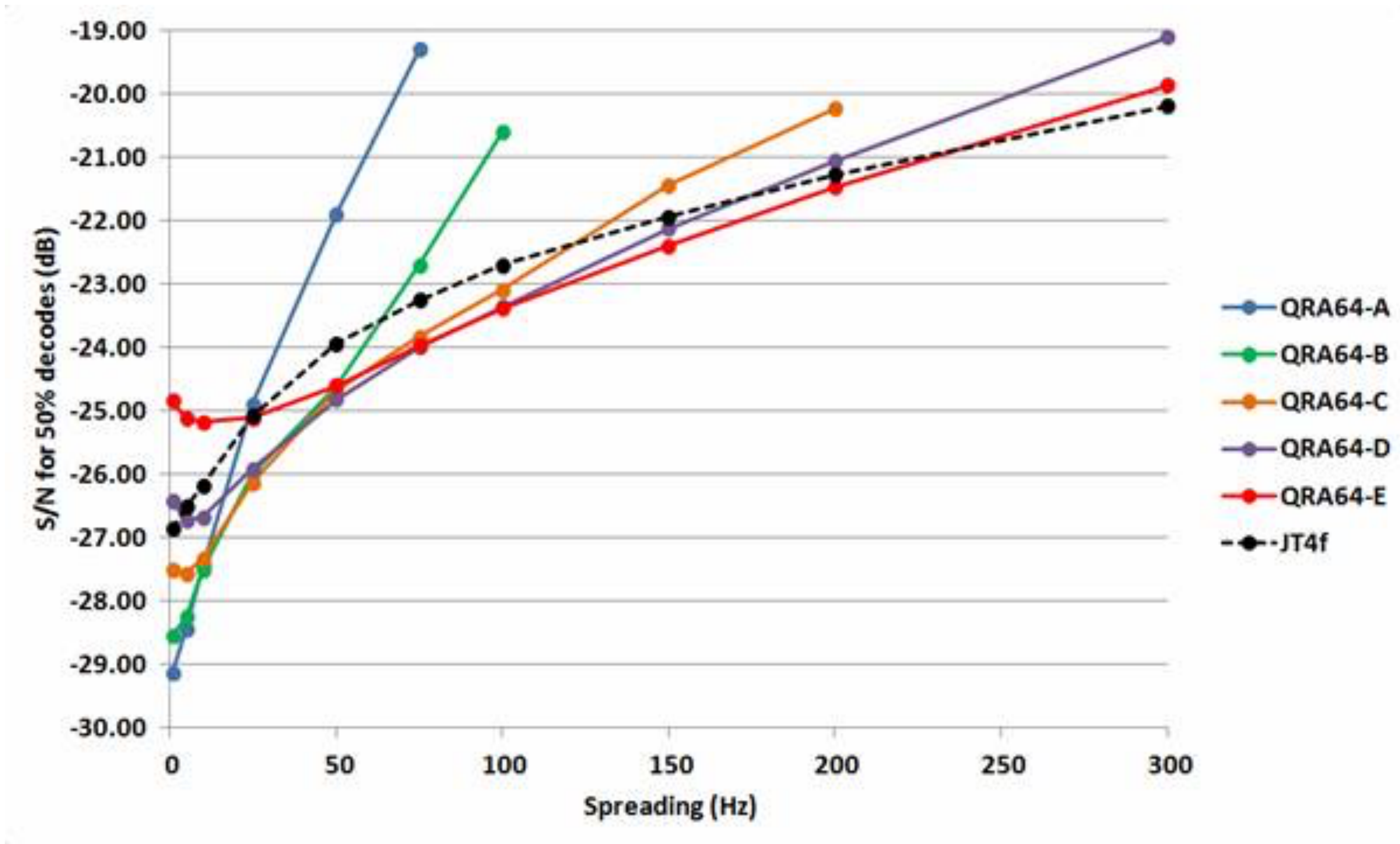
Both modes have been compared with simulated spreading of 50 Hz at 10 GHz. The performance of QRA64 is compared in detail to JT4f at Appendix A and in summary below:

Activity	QRA64 Advantage
Free text	2.8 dB

Working a random station not in the JT4 data base	3.4 dB
Working Sked where both callsigns are known	0.9 dB
Identifying a Beacon where the full message is known	1.9 dB

Simulation Results over a range of spreading

Graph 2 shows the results for various QRA64 sub-modes compared to JT4f and is based on transmitting two callsigns and a report with Deep Search applied to JT4f and prior knowledge of both callsigns applied to QRA (that is the sked situation). In both cases the callsigns are known and the report is unknown so the results are comparable.



Graph 2: Simulated comparison of QRA64 sub-modes to JT4f with spreading at 10 GHz

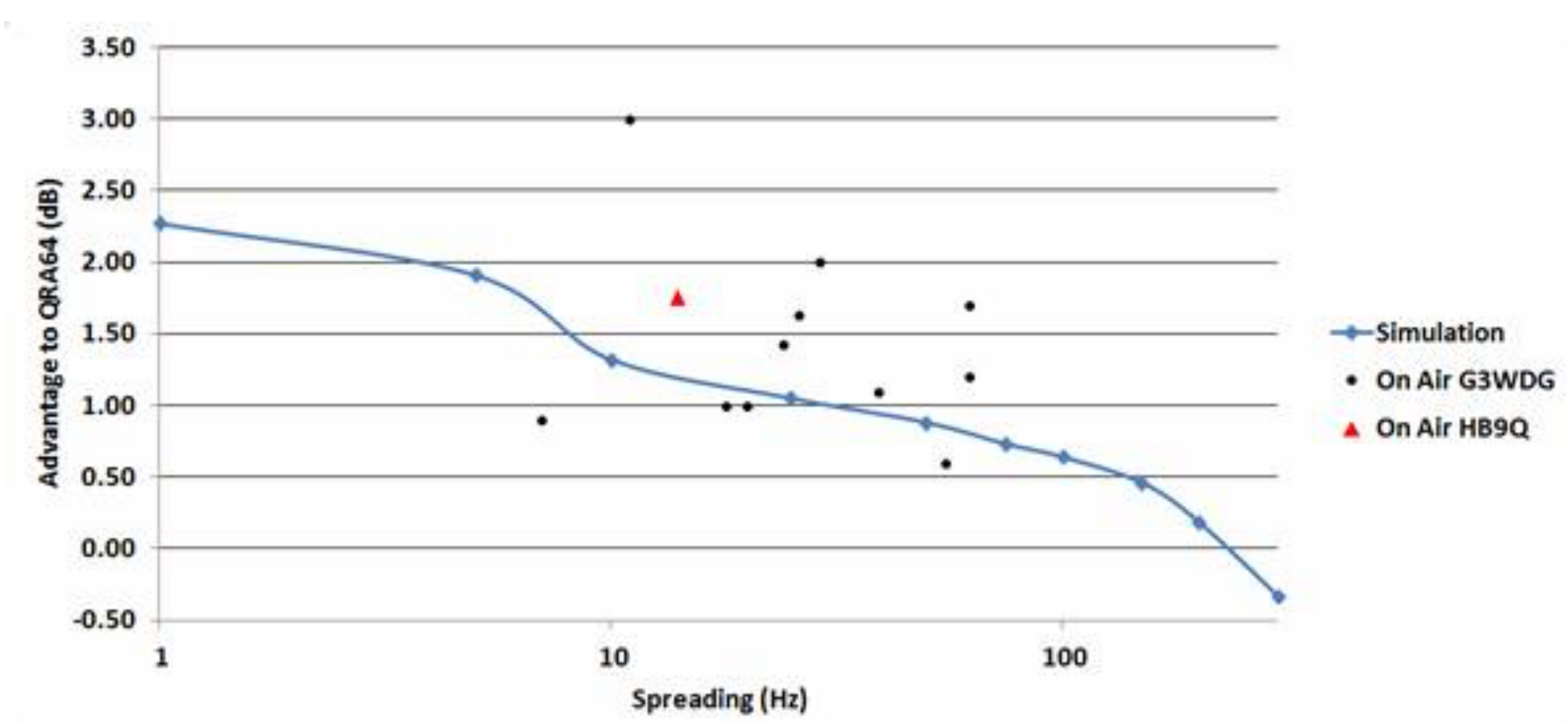
It is seen that over the range 20 to 50 Hz the best QRA64 sub-mode maintains an advantage of around 1 dB over JT4f. At high spreading the advantage of QRA64 diminishes to zero at about 240 Hz spreading. It is noted, however, that at low spreading the wider QRA64 sub-modes such as E tend not to improve and thus one disadvantage of QRA64 is that you need to select the optimum sub-mode in advance and this limits its use for random QSOs at marginal signal levels, where the spreading cannot be determined in advance. (This limitation might be overcome in future versions).

On-air Comparisons

As a check on the performance of the simulators we conducted on-air testing by transmitting QRA64 and JT4 on alternate periods to compare the results. For these tests the power was reduced to the point where both modes were achieving only marginal decodes and then the comparison was made by applying the added noise function of WSJT-X to fine tune the limit of decoding.

Graph 3 gives the results of on air comparisons on a log scale. Each point represents a test during a Moon pass and is based on the analysis of typically 10 periods on each mode at times when both stations have a clear view of the moon.

It is noted that the average of the on-air results are a little above the simulated results suggesting that over the range 20 to 50 Hz QRA is around 1.5 dB in front.



Graph 2: On-air comparisons of QRA64 and JT4 with reference to Simulation results

Use of Prior knowledge to assist with a QSO

The definition of a QSO at VHF was formalised back in 1957 by Tilton in QST[(3)]. Tilton made an important distinction between "identifying" both callsigns and exchanging unknown "information" such as a report. In this respect Tilton took account of the fact that a sked where both callsigns are known is a legitimate QSO but that in addition information that is unknown (such as a report) must be exchanged. An important issue is that in "identifying" a known callsign this must be identified over the air and not a false decode from the noise (this issue arises with all modes when working sked). Accordingly one seeks a low probability of false decodes in "identifying" known callsigns.

False Decodes

JT4 does suffer from occasional false decodes but almost all of these can be rejected by an experienced operator taking account of such factors as consistency of callsigns or by waiting for a second decode when the indicated confidence levels are low.

False decodes do occur with QRA64 but these are extremely rare. Even when running 10,000 simulation tests with marginal signals and changing the callsigns being sent by one letter we did not see one misleading false decode with your own callsign. We see this as a significant advantage of QRA64.

Finding Very Weak Signals

Unlike JT65 both QRA64 and JT4 do not use a single tone sync system that can be readily identified on the waterfall. In the case of QRA64 the program adds a Red marker on the waterfall at the end of each period to indicate where it has detected sync. While this is useful when signals are a few dB above the margin the marker is often not present on a weak signal and sometimes shows up on the wrong frequency (in particular when listening to noise). The solution in the case of both QRA64 and JT4 is to transmit a single tone at the start of a sked so as to find a weak signal. Such tones are provided for both JT4 and QRA64. The same set of single tones are used for JT4 and QRA64, which are as follows:

1000 Hz = Tune (T)

1250 Hz = Please send Messages (M)

1500 Hz = RRR (R)

1750 Hz = 73 (73)

These can be sent in both JT4 and QRA64 by clicking the Sh checkbox, as shown in Fig. 1 below, and then selecting the appropriate TX message box.

Fig 1 Enabling Single tone messages

A 1250 Hz tone is obtained by clicking the TX6 checkbox (show above with the arrow) and selecting Tx6 message button. Alternatively, manually typing @XXXX in any TX box will send a single tone at a frequency of XXXX Hz.

Single tones have to be interpreted by the operator – the program does not do this for you, nor are they recognised by the auto-sequencer (if used). The tones frequencies are read from the waterfall. Single tones are readily seen on the Linear Average average Yellow graph down to -30 dB with 50 Hz spreading and sending a single tone RRR has an advantage of over 4 dB compared to sending Callsigns and RRR as a normal message. An example is shown in Fig 2, which shows a 1000 Hz (or T tone):

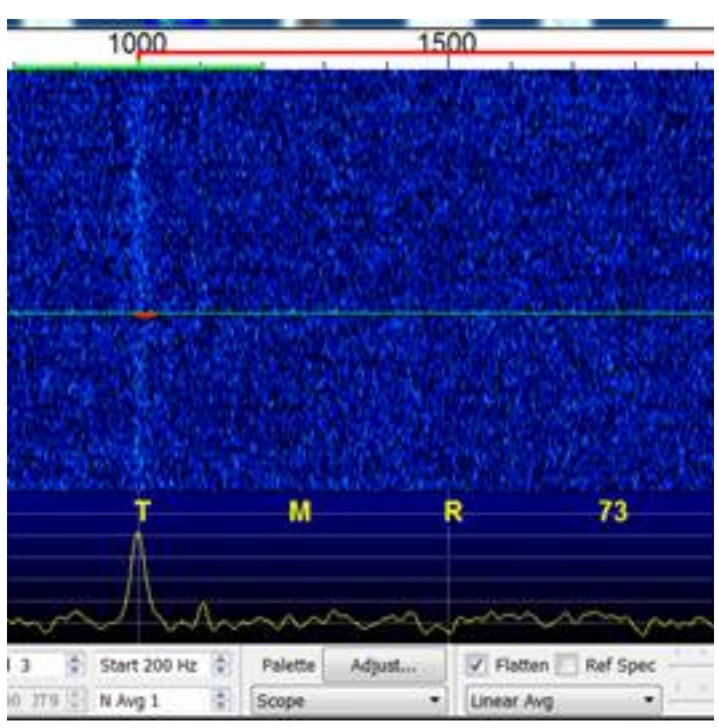


Fig 2 : Single tone on the waterfall.

Averaging

As present QRA64 does not have an averaging facility like JT4f which can gain up to 2 dB if one has time to average over several periods. There is the potential to add averaging to QRA64 and gain a further improvement.

Conclusions

QRA64 does not use a Call3.txt file and has a significant advantage of around 4 dB when working a random station not included in the Call3.txt file.

While QRA64 has a relatively small advantage of around 1.5 dB over JT4f when working sked where both callsigns are known, every dB counts when working marginal EME signals.

An attractive feature of QRA64 is the fact that it is virtually immune to false decodes and thus overall we recommend QRA64 for weak signal 10 GHz EME.

Acknowledgements

Nico Palermo, IV3NWV, and Joe Taylor, K1JT, for designing the QRA mode and implementing it in WSJT-X. K1JT for implementing simulators in WSJT-X. Also thanks Joe and Nico for reviewing this paper and providing many useful suggestions.

References

(1) Nico Palermo, IV3NWV; http://www.eme2016.org/wp-content/uploads/2016/08/EME-2016-IV3NWV-Presentation.pdf

(2} Joe Taylor, K1JT, "*WSJT-X:* New Codes, Modes, and Tools for Weak-Signal Communication" (PowerPoint Slides: 17th International EME Conference, Venice, August 2016)

(3) Tilton E. P W1HDQ " *The World above 50 Mc*" QST, March 1957

(4) A Power Point presentation relating to this paper is at: https://tinyurl.com/ya6484wv

Appendix A

Tests Results for 50% Decoding with 50 Hz Spreading at 10 GHz

	RC= -->											
Message	0	1	2	3	4	5	6	7	8	9	10	11
CQ/QRZ/My Call	?	k	k	k	k	k	?	?	k	k	k	k
DX Call	?	?	?	?	?	k	k	k	k	k	k	k
Report/Grid/73/RRR	?	?	?	?	?	?	?	?	k	?		k
G3WDG VK7MO QE37	-22.7			-23.4		-24.8			-25.8			
G3WDG VK7MO -24	-22.7			-23.4		-24.8						
G3WDG VK7MO No Grid	-22.7			-23.4	-23.9	-24.8		-24.8				
CQ DL0SHF JO54	-22.7	-23.3					-23.6			-24.8		-25.9
CQ DL0SHF No Grid	-22.7	-23.4	-23.7				-23.8	-24.1		-24.8	-25.9	
G3WDG VK7MO RRR	-22.7			-23.4		-24.8						
JT4f Convolutional	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9	-19.9
JT4f Deep Search						-23.9			-23.9	-23.9	-23.9	-23.9
QRA64 to JT4 Convolutional	2.8	3.4	3.8	3.5	3.9	4.9	3.9	4.9	5.9	4.9	6.0	6.0
QRA64 to JT4 Deep Search						0.8			1.9	0.9	1.9	1.9

RC is a return code that indicates the known and unknown information used to achieve a decode.

"k" means this information is known in the sense that it is searched for. However, for example, in the case of the first block while the QRA program searches for CQ, QRZ and My Call and in this sense it is unknown it gains around 0.7 dB from the knowledge that the message is limited to CQ, QRZ or myCall as indicated by an RC value of 1 or 3.

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