How late can a reply start and still be decoded?

FT8, FT4 and FT2 when the other station starts transmitting late, and the receiver already knows part of the message. Measurements with the JTDX_contest decoder, November 2026, and a decoder flaw they found in FT4 and FT2, now fixed.

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In short - the latest start, in seconds into the period, that a strong signal is still decoded from in at least 9 of 10 trials; in brackets, where it still decodes in at least half of them:

Strong signal, 0 dB	Frame on the air	bystander	report	R-report	RR73
FT8 (15 s period)	0.50 - 13.14 s	**6 s** (6.2 s)	**6.4 s** (10.2 s)	**10.7 s** (10.9 s)	**11.2 s** (11.3 s)
FT4 (7.5 s period)	0.45 - 5.49 s	**2.8 s** (2.9 s)	**3.75 s** (3.8 s)	**3.7 s** (3.75 s)	**3.7 s** (3.8 s)
FT2 (3.75 s period)	0.13 - 2.65 s	**1.29 s** (1.32 s)	**1.77 s** (1.8 s)	**1.77 s** (1.95 s)	**1.77 s** (1.8 s)

In FT8 the reply the receiver can predict best survives the latest start: after my R-report, his RR73 still decodes when only the last sixth of the frame is on the air. A bystander, who knows nothing, needs about half of the frame. In FT4 and FT2 the a-priori passes carry every reply beyond the bystander's limit since the fix described in section 7 - his RR73 at 0 dB until 3.7 s in FT4 and 1.77 s in FT2, where before the fix it stopped at the bystander's 2.8 s and 1.29 s. Weaker signals need more of the frame (section 4). In FT8, the decoders that guess the next message without a CRC also produced rare phantoms from pure noise (section 6).

1. The question

A station that decides late - the operator clicked a few seconds into the period, or the decode arrived late - still transmits. JTDX keeps every symbol on its normal time slot and simply leaves out the part of the frame that has already gone by: a start 6 seconds into an FT8 period sends the last 7 seconds of the frame, exactly where they would have been. JTDX starts such a transmission up to 13.64 s into an FT8 period (6.04 s FT4, 3.02 s FT2). The question is how much of the frame the other station needs.

That depends on what the receiver already knows. In a QSO it knows its own call and the call of the station it works, and often what that station can send next: after my R-report, he can only send RR73, RRR or 73. FT8, FT4 and FT2 decoders use that knowledge ("a priori", AP).

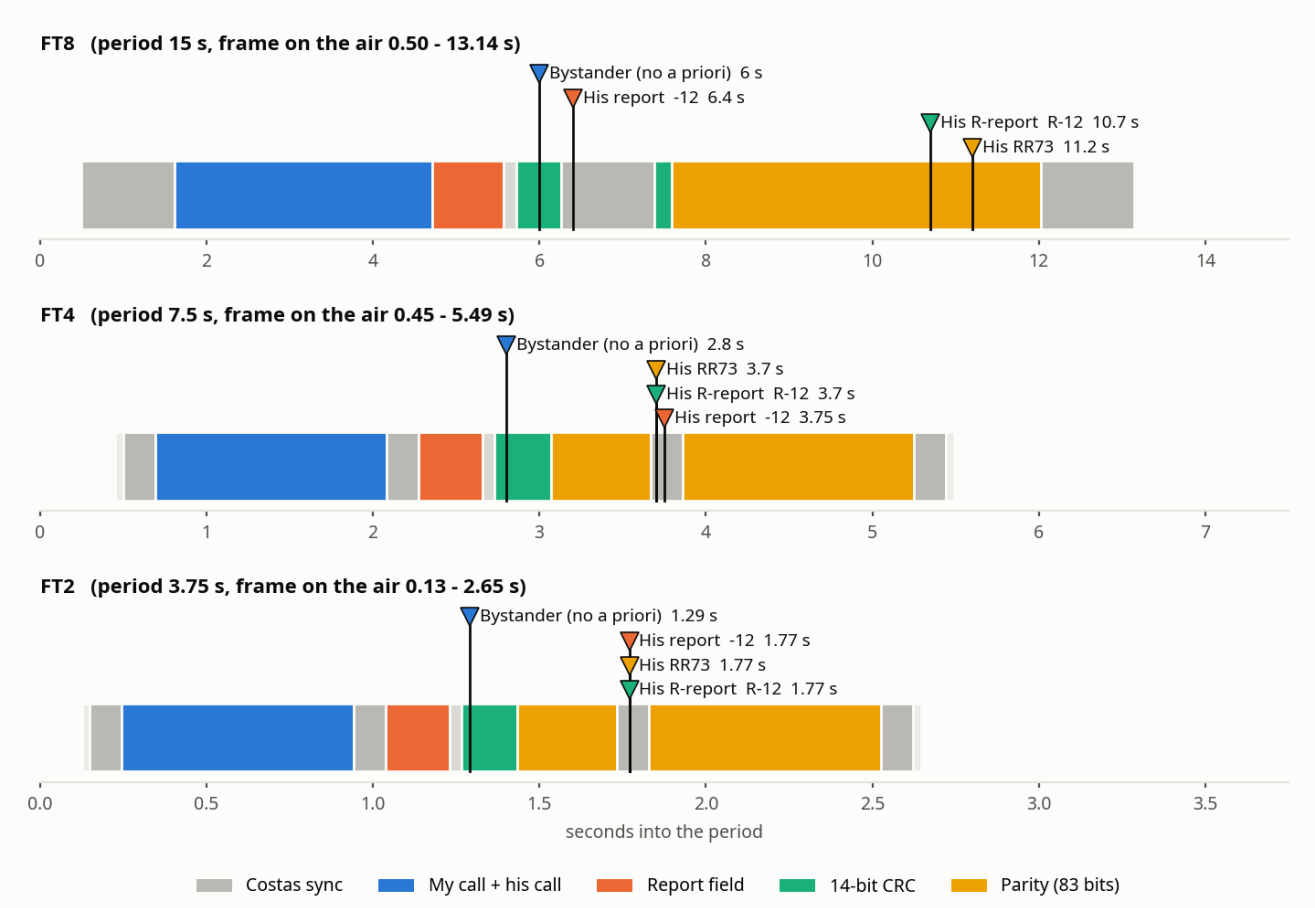


Figure 1. The three frames, field by field, as they sit in the period, and the latest start decoded in at least 9 of 10 trials at 0 dB for each kind of reply. Everything left of a marker is missing in that trial; the receiver has only what lies to its right.

2. Why part of a frame can be enough

Every frame carries 174 bits: the 77-bit message, a 14-bit CRC computed from it, and 83 parity bits of the (174,91) LDPC code. The code is *systematic* and the bits are sent in order, so the start of the frame carries the message itself - first the two calls, then the report or grid - and the end carries only parity (Figure 1). Three kinds of decoder can read a frame:

- **Plain decoding**, which knows nothing. It needs enough of the 174 bits to rebuild all 91 message and CRC bits, and the CRC must check. Losing the beginning of the frame costs it message bits it has no other source for.
- **A-priori passes** (AP). The decoder fixes the bits it already knows - my call, his call, and for RR73 the whole message - and solves only for the rest. A known bit that was never received costs nothing. For RR73 only the 14 CRC bits are left, and they are read from the CRC and parity at the end of the frame. The CRC is what confirms the guess: a wrong message passes it about once in 16,384 tries.
- **Hypothesis decoders** (FT8 only, marked ^ in JTDX). They compare the received tones with the few messages the QSO partner can send next (56 of them) and take the one that matches well enough. There is no CRC in this path.

So a late start hurts least when the missing beginning holds only bits the receiver knows anyway. The CRC also helps plain decoding at the edge: the code alone needs 91 good bits, but when only a few codewords still fit what was received, the 14-bit CRC picks the right one.

3. How it was measured

- The simulators of JTDX_contest (ft8sim with Gaussian shaping, ft4sim, ft2sim) made each frame without noise; everything before the start time was set to zero, the rest scaled to the signal-to-noise ratio (2500 Hz reference) and placed in white noise that fills the whole period.
- Each trial is two periods decoded by one decoder process, as on the air: his previous message at -10 dB, then the late frame two periods later, on the same frequency (1500 Hz), DT 0.
- The QSO context is set as the program sets it: my call K1ABC, DX call W9XYZ, my receive frequency on his, and the QSO step (I had called him / sent my report / sent my R-report). The bystander row decodes the report case's very files as another station (K2DEF) with no DX call and no QSO.
- The decoder is JTDX_contest's jtdxjt9 in file mode with the station recipe (FT8 depth 3, 5 cycles, sensitivity 2; FT4 and FT2 depth 3), one thread, and the receive time budget lifted so that a busy computer cannot read as a decoder limit.
- Six levels per mode, from +10 dB down to near the decoding threshold; start times every 0.5 s (FT8), 0.25 s (FT4), 0.15 s (FT2); 16 trials per point with different noise, the same 16 noise patterns at every start time. At +10 and 0 dB the edges were measured again in steps five times finer, with new noise.
- Noise-only periods (the frame left out completely) with the same QSO context measure phantoms: anything decoded there was not sent.
- 60912 decoder runs in the two measurements (before and after the fix of section 7), 19.8 hours of decoding.

4. Results: how late a start still decodes

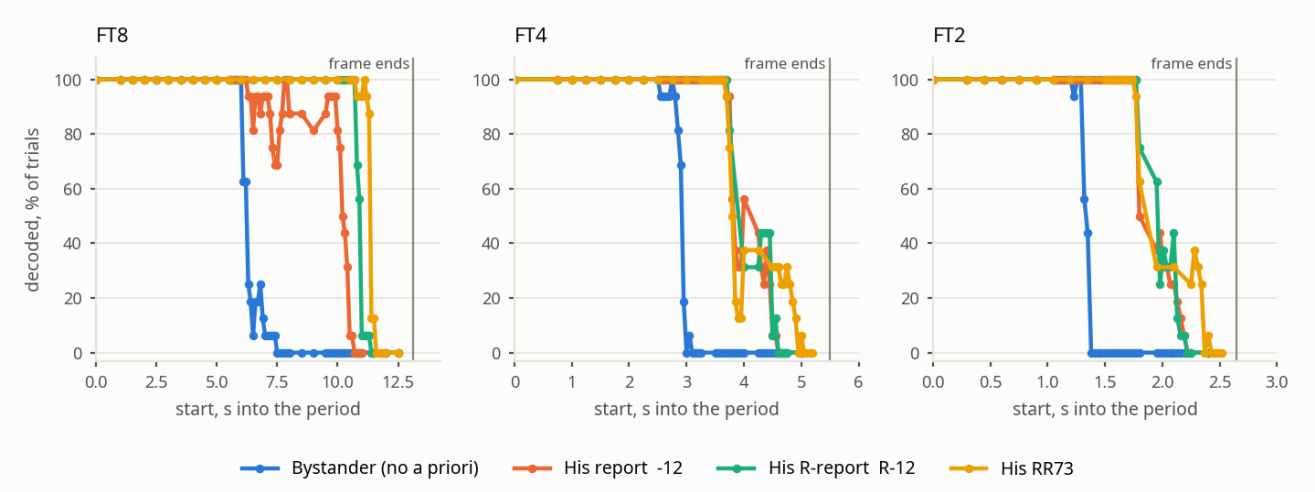


Figure 2. A strong signal (0 dB): the share of trials decoded against the start time. The vertical line is the end of the frame.

The table gives, for every level, the latest start decoded in at least 9 of 10 trials, counted from the full frame (a later start that decodes again after a gap is noted in the text, not here). In brackets: the share of the frame still on the air at that start. "-": even the whole frame was decoded in fewer than 9 of 10 trials at that level.

FT8

FT8 level	bystander	report	R-report	RR73
+10 dB	6 s (56 %)	6.2 s (55 %)	10.6 s (20 %)	11 s (17 %)
+0 dB	6 s (56 %)	6.4 s (53 %)	10.7 s (19 %)	11.2 s (15 %)
-8 dB	6 s (56 %)	6 s (56 %)	10.5 s (21 %)	11 s (17 %)
-14 dB	5 s (64 %)	10 s (25 %)	10.5 s (21 %)	11 s (17 %)
-18 dB	4 s (72 %)	9.5 s (29 %)	9.5 s (29 %)	10.5 s (21 %)
-21 dB	-	8.5 s (37 %)	8 s (41 %)	9 s (33 %)

FT4

FT4 level	bystander	report	R-report	RR73
+10 dB	2.8 s (53 %)	3.75 s (35 %)	3.7 s (36 %)	3.75 s (35 %)
+0 dB	2.8 s (53 %)	3.75 s (35 %)	3.7 s (36 %)	3.7 s (36 %)
-6 dB	2.5 s (59 %)	3.5 s (39 %)	3.75 s (35 %)	3.5 s (39 %)
-11 dB	2 s (69 %)	3.5 s (39 %)	3.75 s (35 %)	3.5 s (39 %)
-15 dB	1.25 s (84 %)	2 s (69 %)	2 s (69 %)	2 s (69 %)
-18 dB	-	-	0 s (100 %)	-

FT2

FT2 level	bystander	report	R-report	RR73
+10 dB	1.29 s (54 %)	1.77 s (35 %)	1.77 s (35 %)	1.77 s (35 %)
+0 dB	1.29 s (54 %)	1.77 s (35 %)	1.77 s (35 %)	1.77 s (35 %)
-3 dB	1.2 s (58 %)	1.65 s (40 %)	1.65 s (40 %)	1.65 s (40 %)
-8 dB	1.05 s (63 %)	1.65 s (40 %)	1.65 s (40 %)	1.65 s (40 %)
-12 dB	0.45 s (87 %)	1.05 s (63 %)	0.9 s (69 %)	0.9 s (69 %)
-15 dB	-	-	-	0 s (100 %)

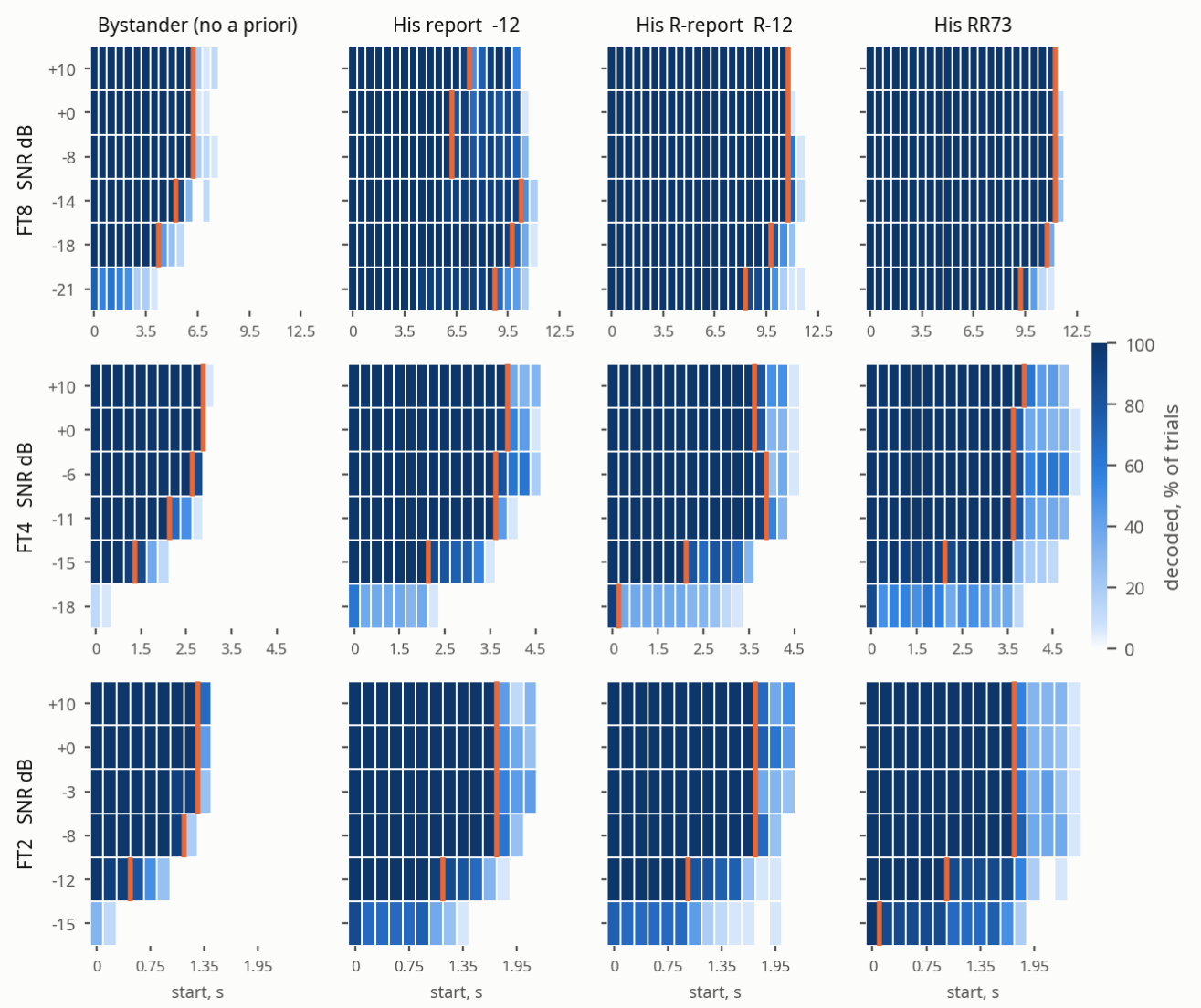


Figure 3. Every measured point: decoded share by start time (across) and level (down), one panel per mode and reply. Dark = always decoded, white = never. The orange tick ends the run of starts decoded in at least 9 of 10 trials.

5. Which decoder takes a late frame

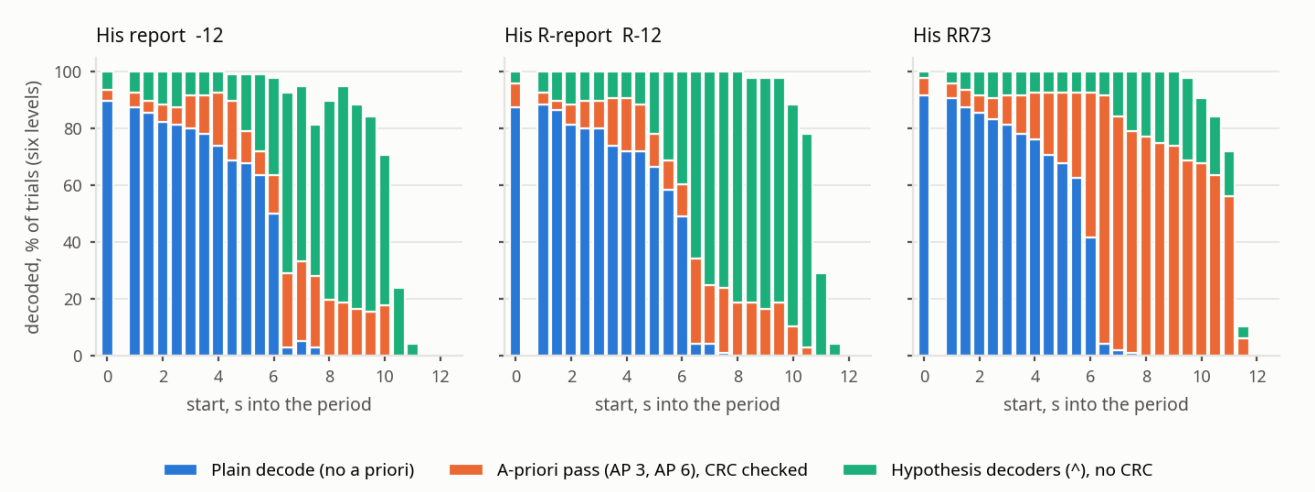


Figure 4. FT8, all six levels together: which decoder produced the decode, by start time. Up to about 6 s plain decoding does most of it; later it is the a-priori pass and the hypothesis decoders.

In FT8, plain decoding - the same decoder a bystander has - carries every reply until about 6 s into the period, when half of the frame is gone. After that, the a-priori pass (AP 3 for a report, AP 6 for RR73) and the hypothesis decoders (^) take over: they decode his report and R-report until about 11 s and his RR73 until 11.5 s. FT4 and FT2 have no hypothesis decoders; their a-priori passes (marked * on the screen) carry every reply beyond the plain limit of 2.8 s (FT4) and 1.29 s (FT2) at 0 dB: his report to 3.75 s and 1.77 s, his R-report to 3.7 s and 1.77 s, his RR73 to 3.7 s and 1.77 s - the last two only since the fix of section 7.

6. How reliable is it? Phantoms from empty periods

A decoder that accepts a message from a sliver of signal could also accept one from noise. Each QSO context was therefore also given periods with no signal at all.

Mode	QSO context of the empty period	Periods	Decoded	What
FT8	bystander	200	0	-
FT8	His report	200	0	-
FT8	His R-report	200	4	K1ABC W9XYZ R-04, K1ABC W9XYZ R-07, K1ABC W9XYZ R-18, K1ABC W9XYZ R-22
FT8	His RR73	200	6	K1ABC W9XYZ -01, K1ABC W9XYZ -11, K1ABC W9XYZ -12, K1ABC W9XYZ -14, K1ABC W9XYZ
FT4	bystander	200	0	-
FT4	His report	200	0	-
FT4	His R-report	200	0	-
FT4	His RR73	200	0	-
FT2	bystander	200	0	-
FT2	His report	200	0	-
FT2	His R-report	200	0	-
FT2	His RR73	200	0	-

FT4 and FT2 decoded nothing in any empty period. FT8 decoded nothing for a bystander or while waiting for his report, but while waiting for his R-report, or for his RR73, a few empty periods gave a message he could have sent - an R-report, a report, once RR73 itself. Every one came from the hypothesis decoders (marked ^ on the screen, no CRC) and was printed at -26 dB; the CRC-checked passes gave none. The late decodes in section 4 are far more frequent than this, so the limits are not phantoms; at the very edge of a limit, a single decode in 16 trials can be one.

7. A flaw this measurement found in FT4 and FT2, and its fix

JTDX_contest checks every decode made with a-priori help against a filter that throws away likely phantoms. One of its rules looks at the third word of the message: four characters are taken for a grid square, and the square is checked against where the other station can be. Two replies have four characters without being meant as squares. "RR73" is even sent as one: the protocol codes the word as grid square RR73, which lies in the Arctic Ocean, where no station is. So the rule found it far from where the other station can be and threw it away. "R-12" does not have the shape, so it was thrown away as a malformed message. FT4 and FT2 try exactly the a-priori passes whose results go through this rule first, and once a message had been thrown away the decoder took any later finding of it for a repeat - so the pass that would have accepted RR73 never ran. With a strong late frame, the plain decoder still read the message as long as about half of the frame was there; after that, nothing did. FT8 was not affected in the same way: its RR73 pass runs on its own, and its hypothesis decoders cover these replies.

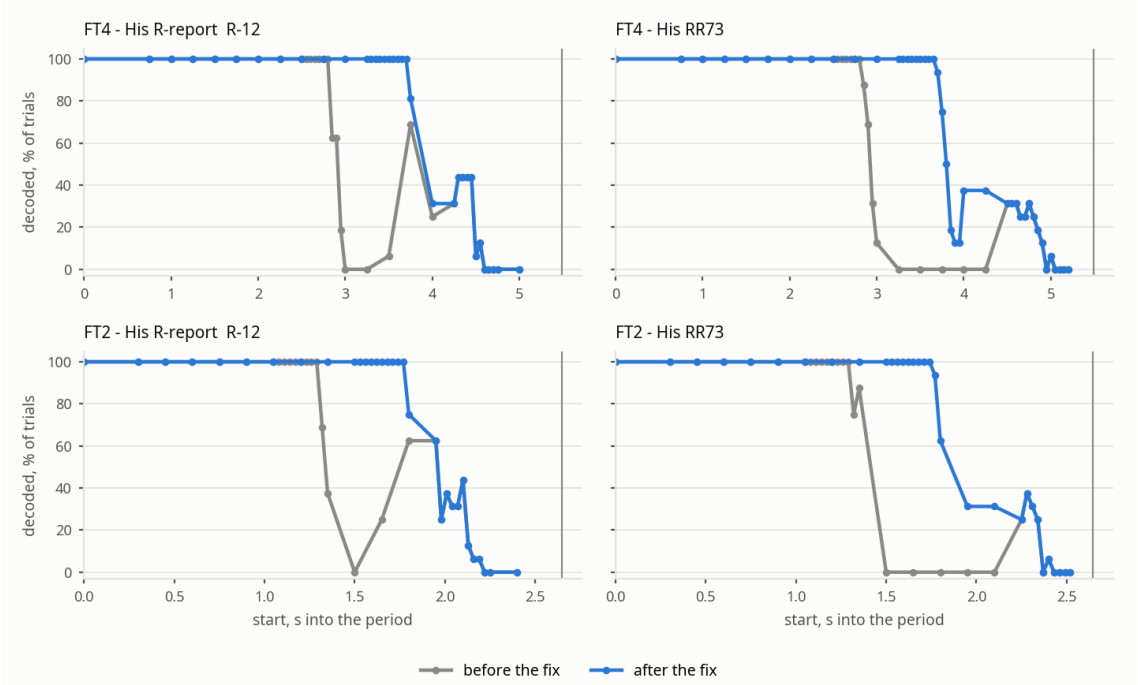


Figure 5. FT4 and FT2 at 0 dB: his R-report and his RR73, the decoder before the fix (grey) and after it (blue). Before, both stopped where a bystander stops; the a-priori passes found the message and the filter threw it away.

Mode	Reply	Level	9 of 10 until: before	after	last decode: before	after
FT4	R-report	+10 dB	2.8 s	**3.7 s**	4.5 s	**4.5 s**
FT4	R-report	+0 dB	2.8 s	**3.7 s**	4.55 s	**4.55 s**
FT4	RR73	+10 dB	2.8 s	**3.75 s**	5.15 s	**5.15 s**
FT4	RR73	+0 dB	2.8 s	**3.7 s**	5 s	**5 s**
FT2	R-report	+10 dB	1.32 s	**1.77 s**	2.16 s	**2.16 s**
FT2	R-report	+0 dB	1.29 s	**1.77 s**	2.19 s	**2.19 s**
FT2	RR73	+10 dB	1.29 s	**1.77 s**	2.4 s	**2.4 s**
FT2	RR73	+0 dB	1.29 s	**1.77 s**	2.4 s	**2.4 s**

The fix (November 2026): an R-report or RR73 from the station being worked is taken as it is, and one from any other station is shown unless its call has a prefix no country uses - the check a reply with a grid square gets. And FT4 and FT2 no longer let a rejected decode stop a later pass that knows the whole message. The fix also helps full frames near the decoding threshold, where the a-priori passes do the work (16 trials each):

The whole frame, near the threshold	Reply	before	after
FT4 at -18 dB	report	10 of 16	**10 of 16**
FT4 at -18 dB	R-report	14 of 16	**15 of 16**
FT4 at -18 dB	RR73	6 of 16	**14 of 16**
FT2 at -15 dB	report	14 of 16	**14 of 16**
FT2 at -15 dB	R-report	11 of 16	**12 of 16**
FT2 at -15 dB	RR73	10 of 16	**16 of 16**

8. Notes and limits

- **A strong, late frame can print nonsense.** At +10 dB a few late frames were decoded as something nobody sent: once in FT8 ("Y46KJY KD5DXG/P PK90", start 3.5 s) and in one FT4 noise pattern at three start times ("<...> <...> 520116 ON16QU"). Every station on the frequency sees such a line.
- **The model.** White noise only - no fading, no other signals; the reply exactly on the receive frequency and on time (DT 0). The late start begins abruptly mid-symbol, as JTDX's transmitter does; the radio's own switching delay is not modelled and costs about one more symbol. The simulators put FT4's and FT2's ramp one symbol earlier than the transmitter does (DT 0.05 s and 0.02 s), well inside what the decoder looks for.
- **Precision.** 16 trials per point: 15 of 16 and 16 of 16 are the same within chance. The strong levels were measured again in steps five times finer around each limit, with new noise; the tables use both.
- **Not measured: an early stop** (Halt Tx halfway, the end of the frame missing). The decoder code suggests FT8 does not rescue it, because the a-priori passes cannot replace the parity at the end.
- **The public decoder.** Before the fix, a sample of 216 trials was decoded again with the decoder of the public JTDX_contest build: 216 gave the same result. The fix is the same in both builds, and its test passes on both.

Measured 2026-11-08 on the JTDX_contest decoder; the simulators, the scripts and every trial's result are kept with the project.

Appendix: every point (decoded of 16 trials)

Main grid. Columns: start time in seconds into the period (0 = the whole frame); rows: level.

FT8 bystander	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5
+10	16	16	16	16	16	16	16	16	16	16	16	16	3	1	2	0	0	0	0	0	0	0	0	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	1	1	0	0	0	0	0	0	0	0	0	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	16	3	2	1	0	0	0	0	0	0	0	0	0	0
-14	16	16	16	16	16	16	16	16	16	16	14	5	0	2	0	0	0	0	0	0	0	0	0	0	0
-18	16	16	16	16	16	16	16	16	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-21	12	9	10	9	8	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FT8 report	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	15	8	12	15	16	15	9	0	0	0	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	13	15	11	14	14	13	14	13	1	0	0	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	16	14	15	13	14	15	14	14	12	5	0	0	0	0
-14	16	16	16	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	15	15	8	3	0	0	0
-18	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	12	6	1	0	0	0
-21	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	15	16	11	8	7	3	0	0	0	0

FT8 R-report	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0	0	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	1	0	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	10	1	0	0
-14	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	12	2	0	0
-18	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	13	8	4	0	0	0
-21	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	14	14	14	8	3	1	1	0	0

FT8 RR73	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	0	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	2	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	4	0	0
-14	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	4	0	0
-18	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15	6	0	0	0
-21	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	14	7	2	1	0	0	0

FT4 bystander	0	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5
+10	16	16	16	16	16	16	16	16	16	16	1	0	0	0	0	0	0	0	0
+0	16	16	16	16	16	16	16	16	16	16	0	0	0	0	0	0	0	0	0
-6	16	16	16	16	16	16	16	16	16	14	0	0	0	0	0	0	0	0	0
-11	16	16	16	16	16	16	16	11	8	1	0	0	0	0	0	0	0	0	0
-15	16	16	16	15	14	6	2	0	0	0	0	0	0	0	0	0	0	0	0
-18	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FT4 report	0	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	16	6	5	5	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	16	15	9	7	1	0	0
-6	16	16	16	16	16	16	16	16	16	16	16	16	16	13	10	10	3	0	0
-11	16	16	16	16	16	16	16	16	16	16	16	16	16	7	1	0	0	0	0
-15	16	16	16	16	16	16	16	14	13	12	12	9	1	0	0	0	0	0	0
-18	10	6	6	6	6	5	6	1	0	0	0	0	0	0	0	0	0	0	0

FT4 R-report	0	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	13	8	8	1	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	16	13	5	5	1	0	0
-6	16	16	16	16	16	16	16	16	16	16	16	16	16	15	4	6	1	0	0
-11	16	16	16	16	16	16	16	16	16	16	16	16	16	15	9	5	0	0	0
-15	16	16	16	16	16	16	16	13	11	13	13	11	5	0	0	0	0	0	0
-18	15	6	6	6	6	6	6	5	5	4	2	1	0	0	0	0	0	0	0

FT4 RR73	0	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5
+10	16	16	16	16	16	16	16	16	16	16	16	16	16	16	10	7	7	4	0
+0	16	16	16	16	16	16	16	16	16	16	16	16	16	12	6	6	5	5	1
-6	16	16	16	16	16	16	16	16	16	16	16	16	16	14	9	10	10	9	1
-11	16	16	16	16	16	16	16	16	16	16	16	16	16	13	7	6	6	5	0
-15	16	15	16	15	15	15	15	14	15	16	16	15	16	5	3	3	2	0	0
-18	14	8	9	9	8	10	9	6	8	8	7	6	6	2	0	0	0	0	0

FT2 bystander	0	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5	1.65	1.8	1.95	2.1	2.25	2.4
+10	16	16	16	16	16	16	16	16	11	0	0	0	0	0	0	0
+0	16	16	16	16	16	16	16	16	7	0	0	0	0	0	0	0
-3	16	16	16	16	16	16	15	15	4	0	0	0	0	0	0	0
-8	16	16	16	16	16	16	15	3	0	0	0	0	0	0	0	0
-12	16	15	15	13	8	4	0	0	0	0	0	0	0	0	0	0
-15	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FT2 report	0	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5	1.65	1.8	1.95	2.1	2.25	2.4
+10	16	16	16	16	16	16	16	16	16	16	16	7	2	5	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	8	6	4	0	0
-3	16	16	16	16	16	16	16	16	16	16	16	9	7	7	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	10	4	0	0	0
-12	16	16	16	16	16	16	15	14	13	11	5	1	0	0	0	0
-15	14	11	11	11	11	12	6	4	1	0	0	0	0	0	0	0

FT2 R-report	0	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5	1.65	1.8	1.95	2.1	2.25	2.4
+10	16	16	16	16	16	16	16	16	16	16	16	11	6	8	0	0
+0	16	16	16	16	16	16	16	16	16	16	16	12	10	7	0	0
-3	16	16	16	16	16	16	16	16	16	16	16	6	5	4	0	0
-8	16	16	16	16	16	16	16	16	16	16	16	11	4	0	0	0
-12	16	16	16	16	16	16	13	13	12	12	4	1	1	0	0	0
-15	12	11	11	11	11	11	7	3	2	1	1	0	1	0	0	0

FT2 RR73	0	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5	1.65	1.8	1.95	2.1	2.25	2.4
+10	16	16	16	16	16	16	16	16	16	16	16	9	5	5	5	1
+0	16	16	16	16	16	16	16	16	16	16	16	10	5	5	4	1
-3	16	16	16	16	16	16	16	16	16	16	16	10	5	7	4	1
-8	16	16	16	16	16	16	16	16	16	16	16	12	6	6	6	1
-12	16	16	16	16	16	16	14	14	14	14	14	9	3	0	1	0
-15	16	14	14	14	14	14	11	11	11	12	8	3	0	0	0	0