

How JG25 found its balance of speed and reliability

The experiments behind the tones, rates, synchronization, coding and receiver - and the limits of the winning design.

12 original graphs	17 complete tables	14 report sections
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Prepared from the reviewed report and the [feature/jg25-history source snapshot](#). Graphs preserve the report's native renderings. All table rows are included, with selectable text and linked evidence. No experiments were rerun.

Contents

Executive Summary	3
The design emerged in eight stages	4
1. Four tones bought rate; slower symbols bought margin	5
2. The radio passband determined where the tones could sit	10
3. The selected constants form a coordinated design	13
4. Protect the header before asking the body to go fast	16
5. Coding and interleaving were selected for useful delivery	20
6. Receiver changes rescued the waveform already on the air	23
7. The retone comparison had to use the repaired receiver	27
8. The selected default favors speed; the family supplies robustness	32
9. Realistic channel fits prevent an overbroad victory claim	36
10. What the selection evidence actually justifies	39
Review corrections and unresolved questions	41
Evidence and reproducibility	43
Source notes and methods	44

Executive Summary

- **Four-tone continuous-phase FSK gave JG25 two bits per symbol while allowing slower symbols than Bell 202.** Tone placement, a protected low-rate header and selectable coding made that useful on restricted FM audio paths. The recovered record demonstrates those tradeoffs; it still contains no numerical four-versus-eight-tone experiment.
- **The receiver made the selected waveform practical.** On the same 36 recorded frames, changing +6 dB/oct conditioning from linear phase to minimum phase raised success from **1/36 to 34/36**, with almost identical magnitude response. A later phase-aware detector recovered **18/18 previously failed JG2400 bodies**, without changing their transmitted bits.
- **Keeping the tones was supported by the later receiver-fixed comparison - with one exception.** The selected JG1800 and JG2400 plans outperformed both tested retunes on all three fitted-channel thresholds. JG2000's 700/1250/1800/2350-Hz candidate still needed about 1.7-2.4 dB less signal and was deferred pending radio validation.
- **JG2400/F0 is a speed-first default.** At 256-byte payloads its waveform carries about **1,881 bit/s versus 926 bit/s for AX1200**, roughly 2.03×. It does not win every robustness comparison: on the three fitted channel models it needs about 3.4-3.9 dB more signal than AX1200 at 90% delivery.

“Best” here means the best-supported compromise for the tested FM paths, receiver and intended use. Robust operation has a different winning profile: F3 lowered the threshold at every JG speed in the later reference sweep.

The design emerged in eight stages

The original problem was to move more useful data through ordinary FM voice audio. The work moved from white-noise prototypes to modeled filters, then to real recordings, production receiver changes and reproducible sensitivity comparisons. A radio replay reuses a saved waveform; it can isolate a receiver change but does not count as a new over-air trial.

Table 1. Development chronology

Period	Design step	Evidence
15-16 Aug	Explore four tones at lower baud; search audio tone placement	Chat simulation
18-20 Aug	Real-radio tilt, receive-emphasis and long-body timing	Radio recordings and replay
26 Aug	Import v0.4 modem and seven-rate wire profile	Repository validation
31 Aug	Minimum-phase emphasis rescues unchanged waveform	Pinned replay; later closure bench
3-4 Sep	Continuous synchronization and phase trellis; F0 default	Recorded RF replay + owner decision
8-10 Sep	Hold PTT across full PHY frames	Virtual cable; owner RF feedback
22-25 Sep	Field failure investigation; receiver fix versus re-toning	Radio replay + fitted-channel simulation
26 Sep-22 Oct	Measure full rate/FEC matrix	Deterministic C++ reference simulations

Reviewed source notes S22. [docs/JG25_DESIGN_HISTORY.md](#) · [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#) · [docs/JG25_INTEGRATION_HISTORY.md](#)

1. Four tones bought rate; slower symbols bought margin

Bell 202 conveys one bit per symbol at 1200 baud. Four tones convey two: at 800 baud, JG's early candidate already carried 1600 raw bit/s. The first 1200-baud four-tone attempt doubled rate but suffered substantially more errors. Slowing the symbols and widening spacing brought a 1920-bit/s candidate near Bell 202's BER in the simplified AWGN test.

The graph uses one consistent run with 550/1250/1950/2650-Hz tones. At -2 dB, BER was 0.030% at 800 baud, 0.162% at 960 baud and 1.293% at 1200 baud. This did not yet include the full voice channel. [Recovered tables](#).

FIGURE 1 / 1. FOUR TONES BOUGHT RATE; SLOWER SYMBOLS BOUGHT MARGIN

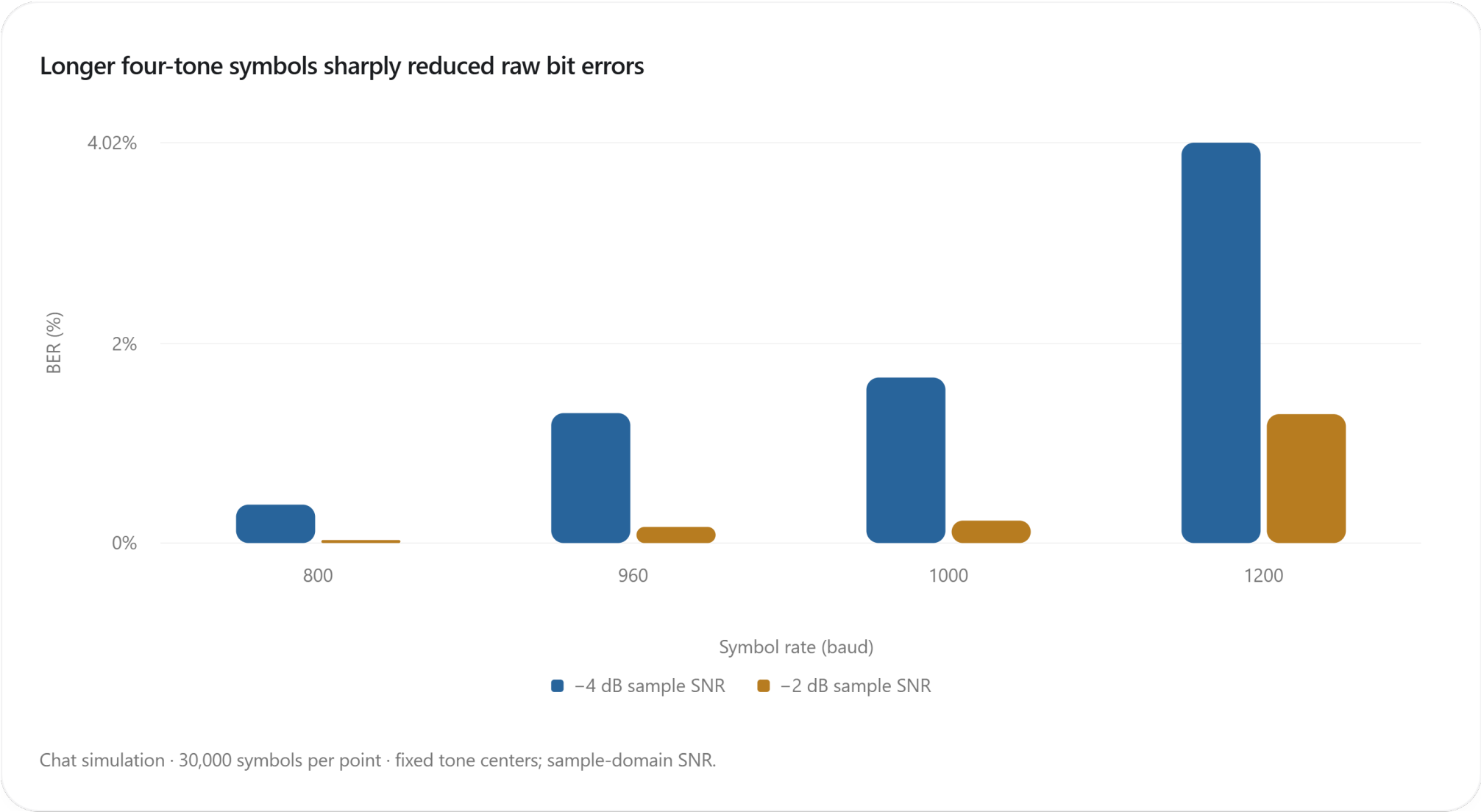


Figure 1. Reviewed source note S1. Full methods and linked sources appear in the appendix.

FIGURE 2 / 1. FOUR TONES BOUGHT RATE; SLOWER SYMBOLS BOUGHT MARGIN

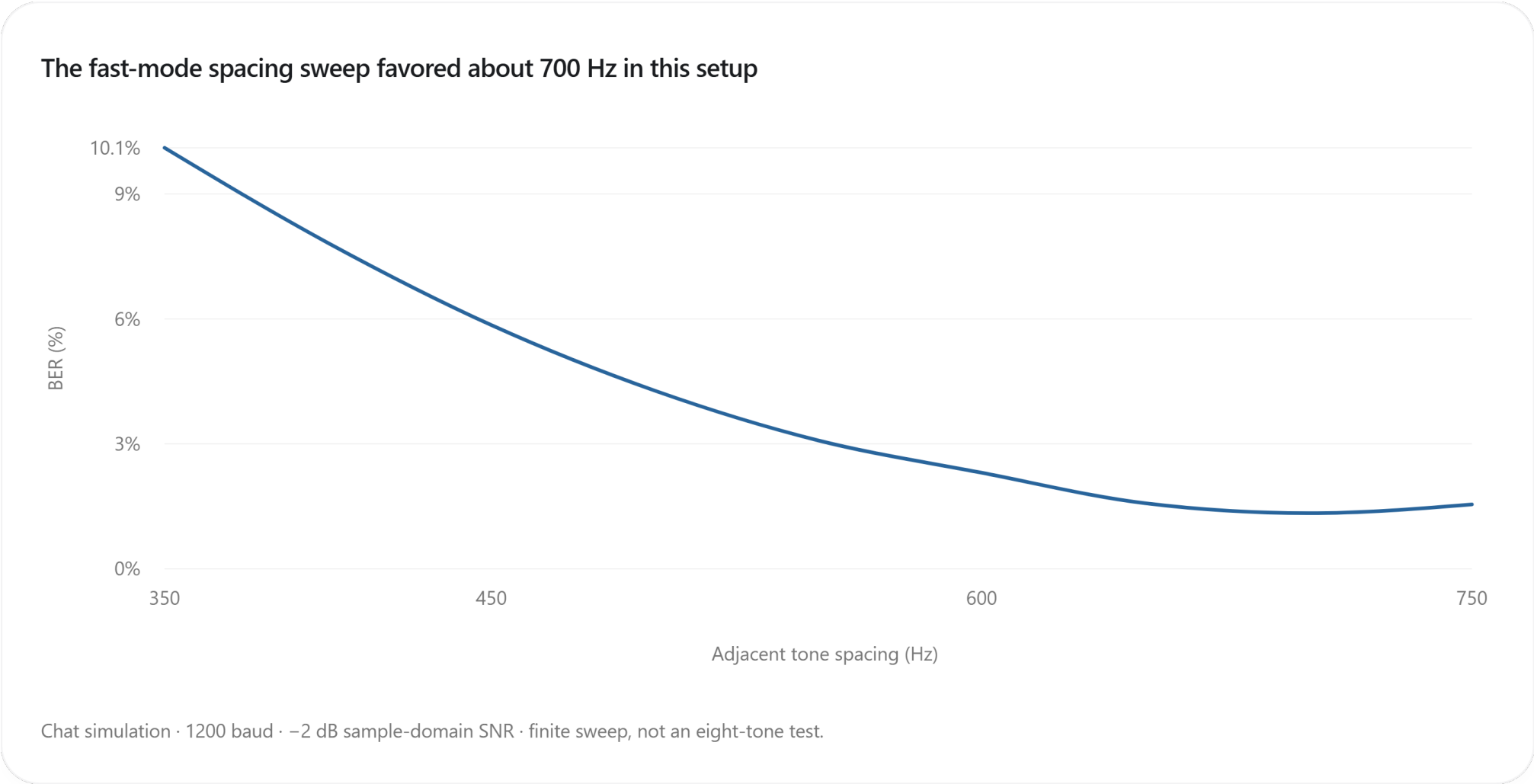


Figure 2. Reviewed source note S2. Full methods and linked sources appear in the appendix.

Table 2. Early rate tradeoff, fixed tone centers

Baud	Raw bit/s	BER at -4 dB (%)	BER at -2 dB (%)
800	1,600	0.385	0.030
960	1,920	1.303	0.162
1,000	2,000	1.660	0.225
1,200	2,400	4.017	1.293

Reviewed source notes S1. [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

Table 3. What was tested and what remained an idea

Alternative	Recovered evidence	What it establishes
Bell 202, two tones	Direct simulated comparator	One bit/symbol at 1200 baud; centrally placed tones tolerated narrow audio well.
Continuous-phase four tones	Simulations + real-radio recordings + implementation	Two bits/symbol; slower symbols and searched placement gave useful rate/sensitivity choices.
Three tones	Discussed; no recovered comparative run	No simple fixed binary bits-per-symbol mapping; not adopted.
Eight / sixteen tones	No completed numerical comparison recovered	Owner recalls higher-tone tests losing; specific results remain unavailable.
QPSK / DQPSK	Discussed; no recovered head-to-head result	Rejected in the discussion over receiver/channel complexity; no measured superiority claim here.
Multi-h CPM + LDPC + incremental redundancy	Brainstorm proposal	Higher-rate ambition, not a validated replacement in the recovered record.
Smooth tone transitions	Later modeled-channel trial	A 4/8/12-sample-ramp exploration increased errors in the cited screen; not proof against every shaping design.

Reviewed source notes S26. [JG25_DESIGN_HISTORY.md](#) · [JG25_DESIGN_HISTORY_ADDENDUM.md](#) · [JG25_INTEGRATION_HISTORY.md](#)

The spacing sweep is evidence that packing even four tones too closely hurt this detector. It is **not** a measured penalty for 8-FSK or 16-FSK. More tones would buy more bits per symbol while forcing a spacing, duration or bandwidth tradeoff; that is a sound engineering explanation, not the missing historical experiment.

2. The radio passband determined where the tones could sit

The original four-tone plan pushed its outer tones toward the audio passband edges. At -2 dB, narrowing the modeled path raised the 1600-bit/s candidate's BER from 0.228% to 2.753%; Bell 202, whose tones sit centrally at 1200/2200 Hz, remained below 0.4%. Those results turned a simple bit-rate proposal into a tone-placement search.

Sweeps varied spacing and center frequency across typical and narrow filters. At 800 baud, moving to 725/1275/1825/2375 Hz reduced narrow-path BER from 0.595% for the round 600/1200/1800/2400-Hz plan to 0.302% in a later optimization run. That is about 49% fewer raw bit errors in that comparison - not an RF sensitivity measurement.

FIGURE 3 / 2. THE RADIO PASSBAND DETERMINED WHERE THE TONES COULD SIT

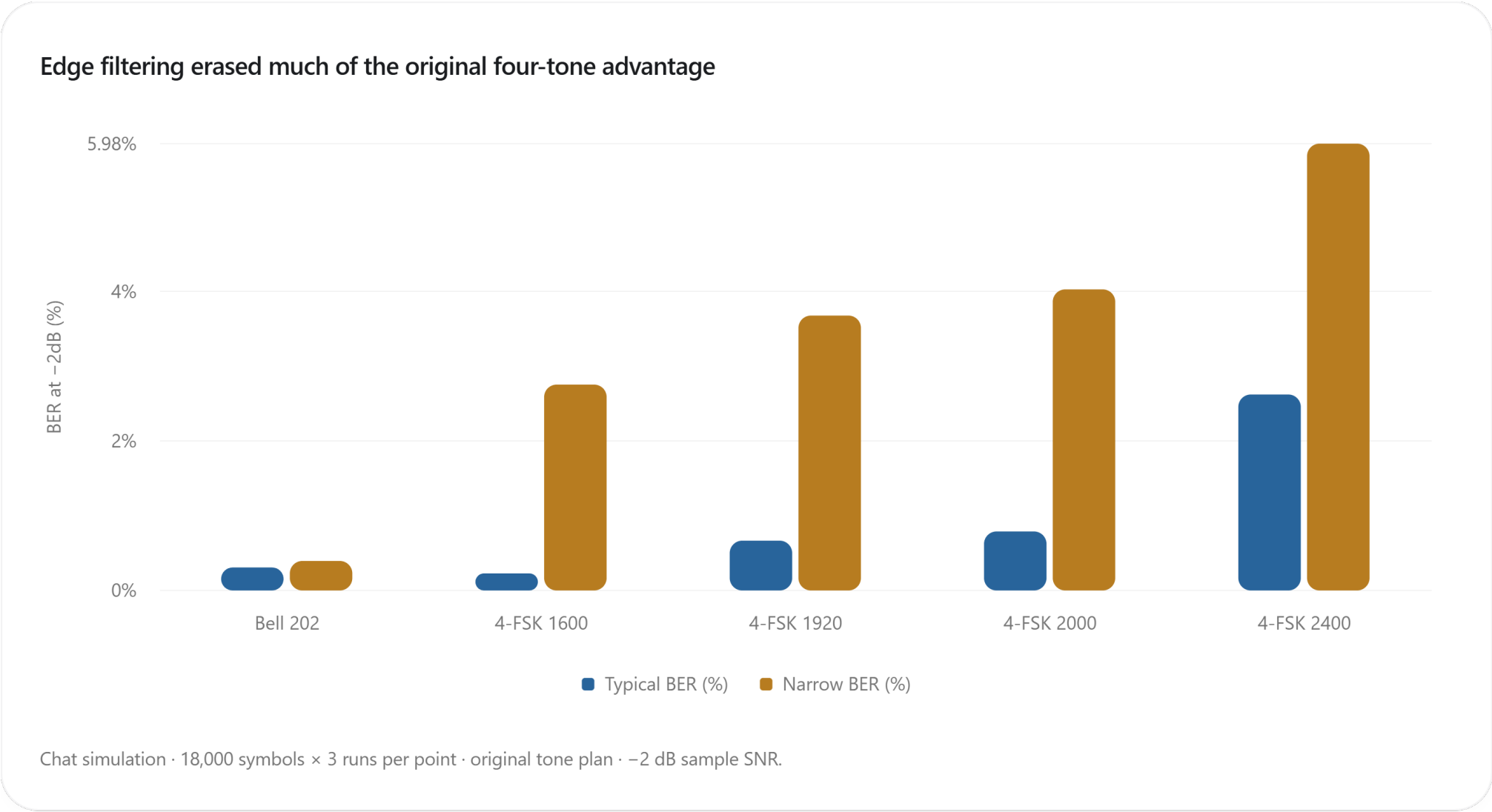


Figure 3. Reviewed source note S3. Full methods and linked sources appear in the appendix.

Table 4. The family search retained useful steps rather than every candidate

Candidate	Raw bit/s	Typical 1%-BER SNR(dB)	Narrow 1%-BER SNR(dB)
Bell 202	1,200	-3.54	-2.98
JG1200	1,200	-5.97	-5.44
JG1400	1,400	-5.04	-4.47
JG1500 (dropped)	1,500	-4.19	-3.76
JG1600	1,600	-4.26	-3.25
JG1800	1,800	-3.13	-1.63
JG1920 (dropped)	1,920	-2.62	-1.15
JG2000	2,000	-2.47	-0.95
JG2200 (early)	2,200	-1.12	1.31
JG2400 (early)	2,400	0.76	1.95

Reviewed source notes S5. [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

The family kept 1200, 1400, 1600, 1800, 2000, 2200 and 2400 bit/s. The 1280, 1500 and 1920 points lacked distinct enough roles; 1920 is only 80 bit/s below 2000. JG2200 initially looked expensive in SNR, but context-aware reception recovered enough margin to retain it. These are early prototype rankings: the final two fast tone plans and the later production receiver differ.

3. The selected constants form a coordinated design

Each mode's number is its **raw coded-bit rate**. JG2400 is 1200 baud, not 2400 baud. Symbol duration, tone spacing and the receiver must be evaluated together.

Four shipped tone vectors trace directly to printed family-search winners; JG2000's vector was printed too, with incomplete explanation of its retention. The final changes for JG2200 and JG2400 were not recovered. Their later retention is supported by a separate September comparison, discussed below. [Profile constants](#).

Table 5. Selected FM tone plans

Mode	Baud	Symbol (ms)	Tone centers (Hz)	Spacing (Hz)	Tone span (Hz)
JG1200	600	1.667	500 / 1100 / 1700 / 2300	600	1,800
JG1400	700	1.429	725 / 1275 / 1825 / 2375	550	1,650
JG1600	800	1.250	775 / 1325 / 1875 / 2425	550	1,650
JG1800	900	1.111	475 / 1125 / 1775 / 2425	650	1,950
JG2000	1,000	1.000	525 / 1175 / 1825 / 2475	650	1,950
JG2200	1,100	0.909	475 / 1125 / 1775 / 2425	650	1,950
JG2400	1,200	0.833	500 / 1200 / 1900 / 2600	700	2,100

Reviewed source notes S4. [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#) · [modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

Table 6. Header and acquisition geometry

Item	Selected geometry	Meaning
Gray symbols	00 / 01 / 11 / 10	Two coded bits per tone symbol
Header inputs	3 mode + 2 FEC + 11 length + 16 CRC	32 bits enter encoder; +6 zero tail
Header output	$2 \times (32 + 6) = 76$ coded bits	38 four-tone symbols
NORMAL start	48/600 +20/600 +38/350	221.905 ms before body
ROBUST start	96/600 +20/600 +38/350	301.905 ms before body
Body FEC mother	K=7, octal 171/133	F1/F2 puncture; F3 unpunctured
Maximum common frame at import	384 bytes	Larger CRC-valid PHY can still be rejected too_long

Reviewed source notes S24. [docs/JG25_DESIGN_HISTORY.md](#) · [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#) · [modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

Table 7. How each selected tone plan entered the design

Mode	Recovered origin / remaining gap
JG1200	Direct family-search winner
JG1400	Direct family-search winner; also early AX1600 vector
JG1600	Direct family-search winner
JG1800	Direct family-search winner; earlier 960-baud grid winner
JG2000	Printed family-search winner; retention detail incomplete
JG2200	Final change from the early 525-Hz-start vector not recovered
JG2400	Final change from early 600/1200/1800/2400 not recovered

Reviewed source notes S4. [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#) · [modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

Tone span is the distance between outer tone centers. It is smaller than occupied audio bandwidth because modulation creates spectral skirts. The later 99%-power audio measurements were about 2.47-2.53 kHz for the three slowest modes and up to 3.17 kHz for JG2400. Those are rendered-audio figures, not measurements of an FM transmitter's RF occupied bandwidth. [Bandwidth method](#).

4. Protect the header before asking the body to go fast

The receiver must learn mode, FEC and length before decoding the body. Early tests often detected the preamble but lost the protected header. The selected 350-baud, four-tone header devoted 108.6 ms to those 38 symbols, compared with 63.3 ms at 600 baud.

At -6 dB in the isolated-header contest, 350 baud achieved 96.7% success versus 33.8% at 600 baud. A 600-baud 2-FSK header needed 126.7 ms yet reached 54.2%; repeating the 600-baud 4-FSK header also used 126.7 ms and reached 90.4%. The slower four-tone header was the better tested airtime/reliability compromise.

FIGURE 4 / 4. PROTECT THE HEADER BEFORE ASKING THE BODY TO GO FAST

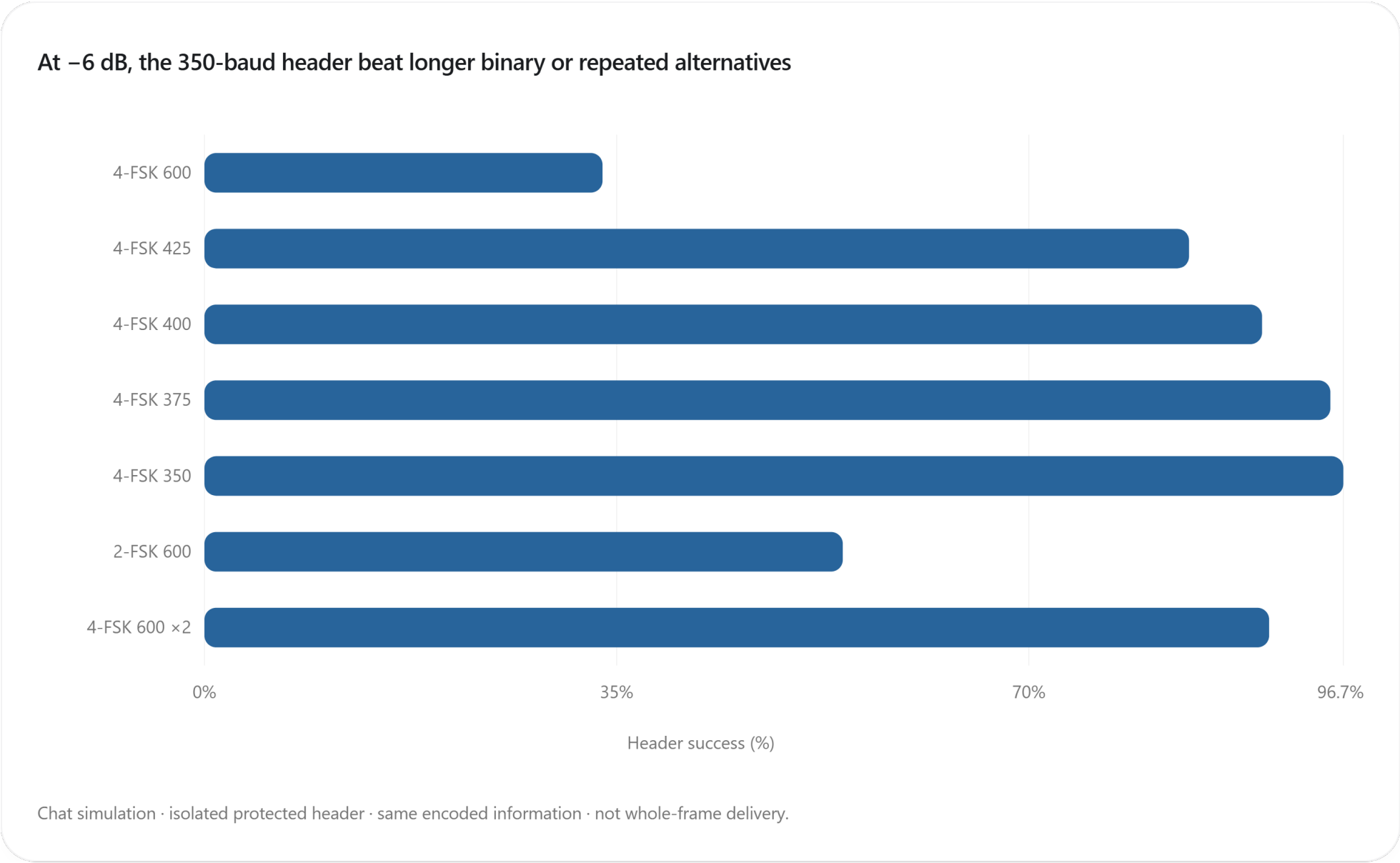


Figure 4. Reviewed source note S6. Full methods and linked sources appear in the appendix.

FIGURE 5 / 4. PROTECT THE HEADER BEFORE ASKING THE BODY TO GO FAST

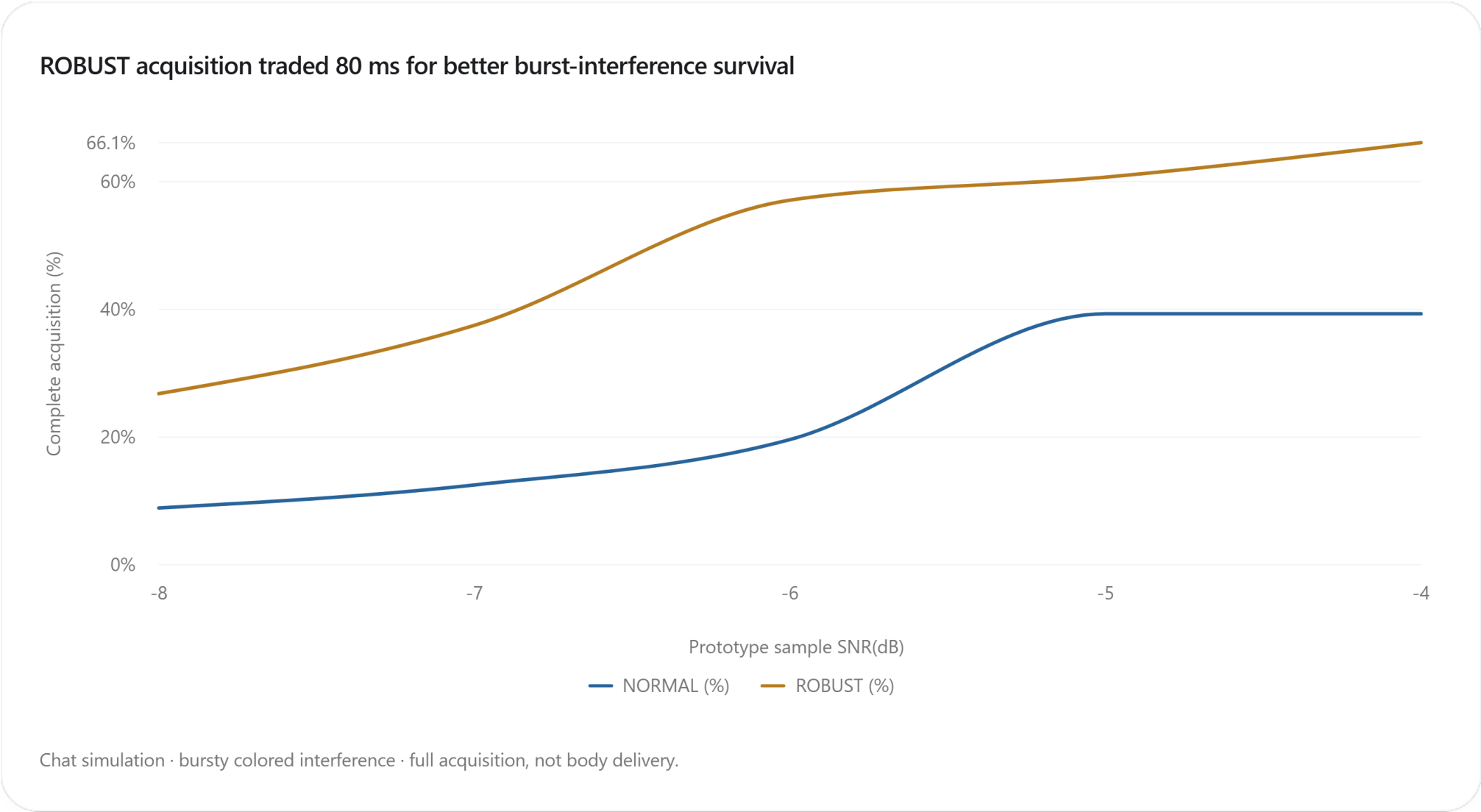


Figure 5. Reviewed source note S7. Full methods and linked sources appear in the appendix.

Table 8. Header alternatives in the same simulated contest

Header scheme	Airtime (ms)	-8 dB(%)	-6 dB(%)	-4 dB(%)
4-FSK 600	63.3	3.6	33.8	90.7
4-FSK 425	89.4	23.1	83.6	99.8
4-FSK 400	95.0	26.7	89.8	100.0
4-FSK 375	101.3	44.4	95.6	100.0
4-FSK 350 - selected	108.6	53.1	96.7	100.0
2-FSK 600	126.7	9.3	54.2	99.6
4-FSK 600, repeat ×2	126.7	29.6	90.4	100.0

Reviewed source notes S6. [docs/JG25_DESIGN_HISTORY.md](#) · [docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

NORMAL uses 48 preamble symbols; ROBUST uses 96 with a common prefix. Including 20 sync symbols and the 350-baud header gives 221.9 ms and 301.9 ms before the body. A 300-baud header improved its isolated results further, but complete-acquisition gains were smaller once preamble detection became the bottleneck. A 64-symbol preamble did not consistently beat 48.

Zero false acquisitions in 320 fresh simulated noise recordings was a bounded test, not a zero-false-alarm guarantee. Later, receive was fixed to recognize both acquisition profiles independently of the station's transmit setting.

5. Coding and interleaving were selected for useful delivery

The waveform supports four FEC profiles around the same $K=7$ convolutional mother code. The header identifies the choice, so peers need not transmit at identical rates or coding. F0 retains CRC protection while removing coding overhead.

Interleaving spreads concentrated errors before Viterbi decoding. The direct waveform simulation was more informative than the first FEC model, which replaced raw BER with an equivalent binary-AWGN channel and lost error correlation. At JG1800-F2,32 rows reduced FER from 54.7% to 20.3% in the cited -5 dB case.

FIGURE 6 / 5. CODING AND INTERLEAVING WERE SELECTED FOR USEFUL DELIVERY

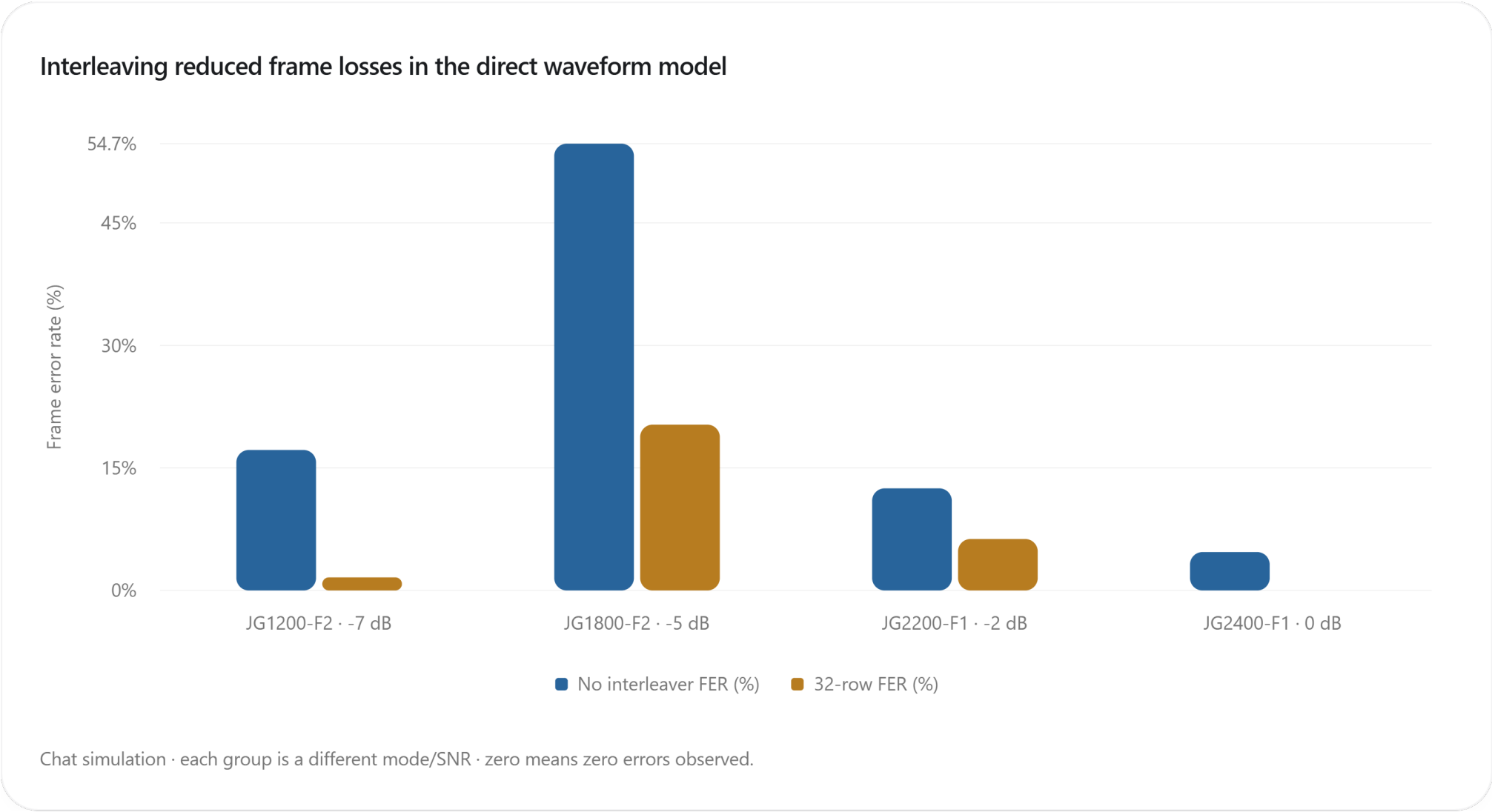


Figure 6. Reviewed source note S8. Full methods and linked sources appear in the appendix.

Table 9. Selected body-protection profiles

Profile	Protection	Nominal rate	Interpretation
F0	Uncoded; CRC-32C	1.000	Maximum clean-path payload rate
F1	K=7 (171,133), puncture 111001	0.750	Nominal 3/4; later modest or negative sensitivity gain above JG1200
F2	K=7 (171,133), puncture 1110	0.667	Nominal 2/3; some gain, with airtime cost
F3	K=7 (171,133), unpunctured	0.500	Most robust measured profile at every speed

Reviewed source notes S9. [docs/JG25 DESIGN HISTORY.md](#) · [docs/JG25 INTEGRATION HISTORY.md](#) · [fixtures/modem_comparison_2026-09/README.md](#)

The selected interleavers were 8 rows for the header and 32 for coded bodies. Frame sizes 64, 128, 256 and 512 bytes were tested; an early extrapolation favoring 512 bytes was too optimistic. Direct trials made 256 bytes a useful historical compromise, while shorter bodies helped adverse paths.

The later production-code measurements below supersede the early “more coding always helps” intuition: F1 and F2 often added airtime without a useful threshold gain above JG1200. F3 was the consistent robustness option.

6. Receiver changes rescued the waveform already on the air

The real FT-8800→FT-817 path measured roughly -4.3 to -4.4 dB/octave of receive tilt. Audio-domain emphasis rescued 8/8 JG2000-F1, 8/8 JG2000-F2 and 12/12 JG2400-F1 recordings that had all failed unconditioned. This reversed the early idea that tone choice alone should remove the need for equalization.

The strongest controlled comparison came later: keep the +6 dB/oct magnitude response nearly identical, change its phase realization, and replay the same 36 frames. Success rose from 1 to 34. Low-tone delay, rather than insufficient nominal signal level, had been smearing symbol transitions. Raising the minimum-phase slope further recovered the remaining two in that particular replay set.

FIGURE 7 / 6. RECEIVER CHANGES RESCUED THE WAVEFORM ALREADY ON THE AIR

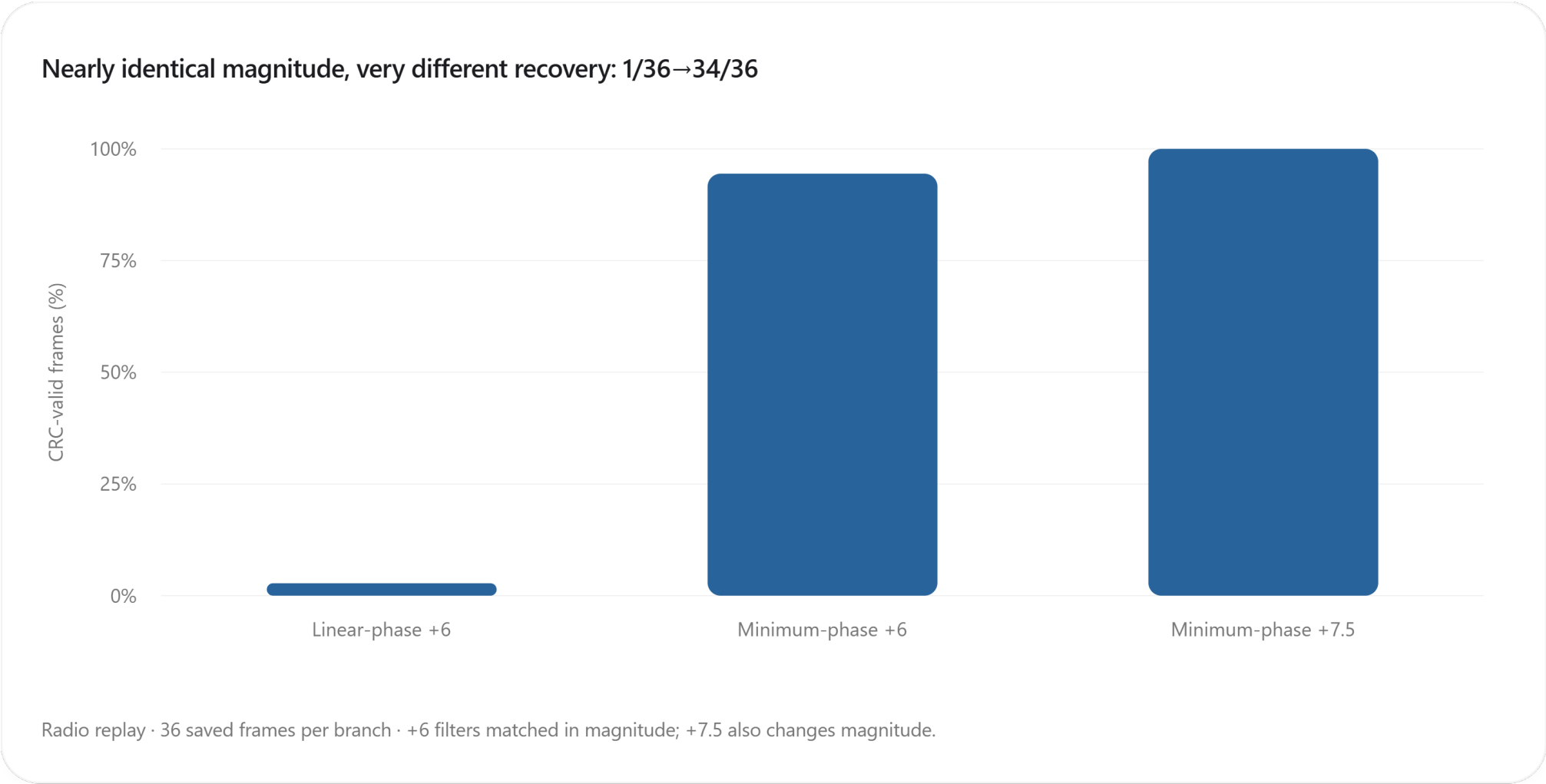


Figure 7. Reviewed source note S11. Full methods and linked sources appear in the appendix.

FIGURE 8 / 6. RECEIVER CHANGES RESCUED THE WAVEFORM ALREADY ON THE AIR

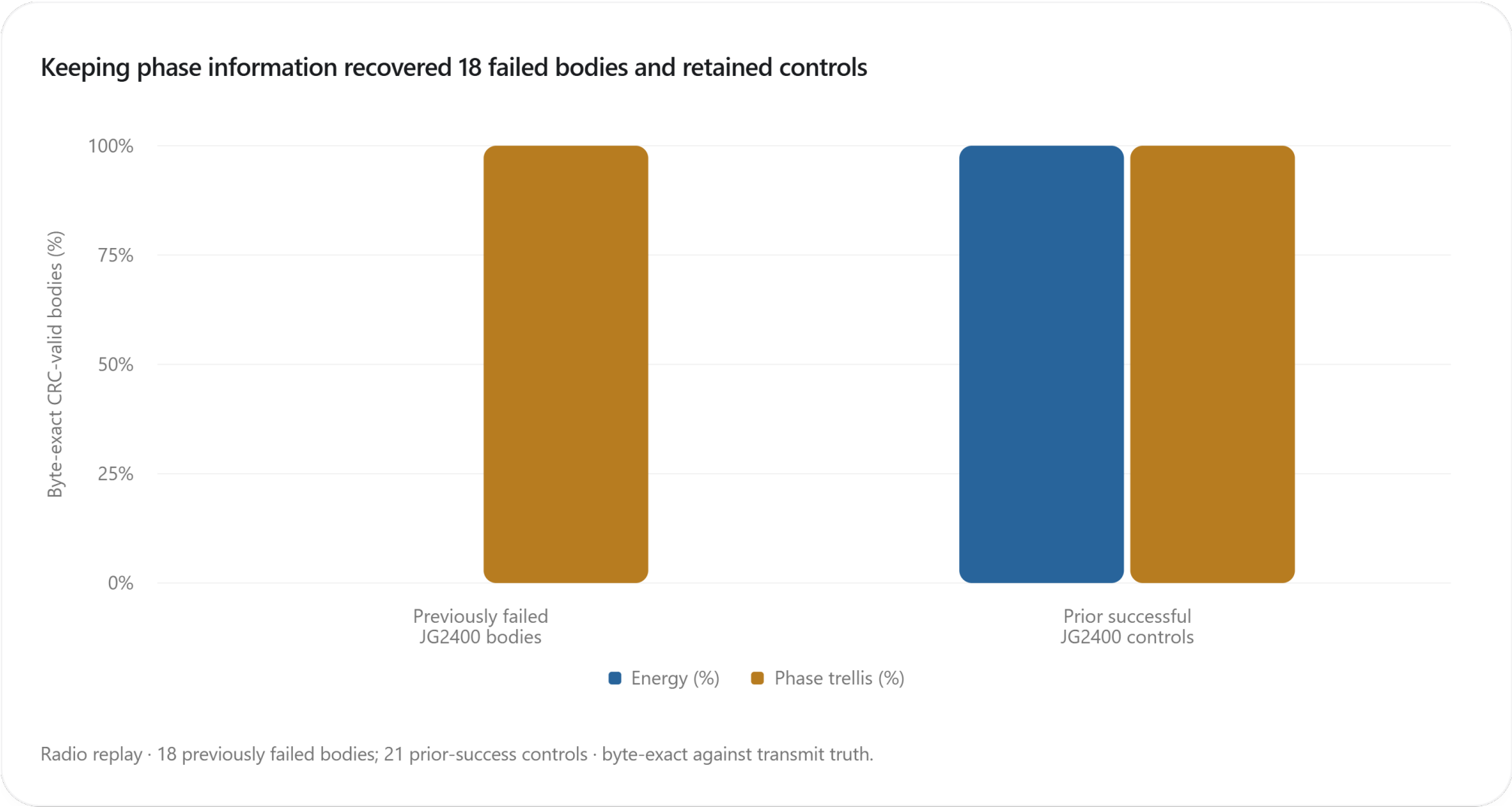


Figure 8. Reviewed source note S12. Full methods and linked sources appear in the appendix.

Table 10. Phase-aware decoding on the recorded September 2 JG2400 bodies

Population	Bodies	Energy detector	Phase trellis
Previously failed JG2400 bodies	18	0	18
Prior successful JG2400 controls	21	21	21

Reviewed source notes S12. [docs/JG25 INTEGRATION HISTORY.md](#)

At 1200 baud and 700-Hz spacing, JG2400's tones are not orthogonal inside a 40-sample symbol window. The phase-trellis detector followed continuous carrier phase across symbols rather than discarding it in four independent energy decisions. Its 48 states are carrier-phase states, not 48 tones.

A continuous synchronizer also found packets inside captures opened by noise or transmit transients. Runtime audio loss, queueing and keying defects were fixed separately. This matters historically: failures caused by missing audio or an unsuitable detector were not proof that the transmitted tone plan needed replacement. [Integration history, §§2-5](#).

7. The retone comparison had to use the repaired receiver

September's field failures reopened tone selection. The slow modes placed their bottom tones at 725-775 Hz, while several fast plans used 475-525 Hz. On fitted real-radio audio, the lower tones incurred much more group delay. At 475 Hz the raw delay relative to 1500 Hz was about 31 samples; at 775 Hz it was 10 samples. A 40-sample JG2400 symbol makes that channel memory consequential.

Moving tones upward often beat the unpatched receiver by a large margin. But the ranking changed when a preamble-trained inverse filter and phase recovery were enabled. The fair question became: **which tones work best with the receiver that will actually ship?**

FIGURE 9 / 7. THE RETONE COMPARISON HAD TO USE THE REPAIRED RECEIVER

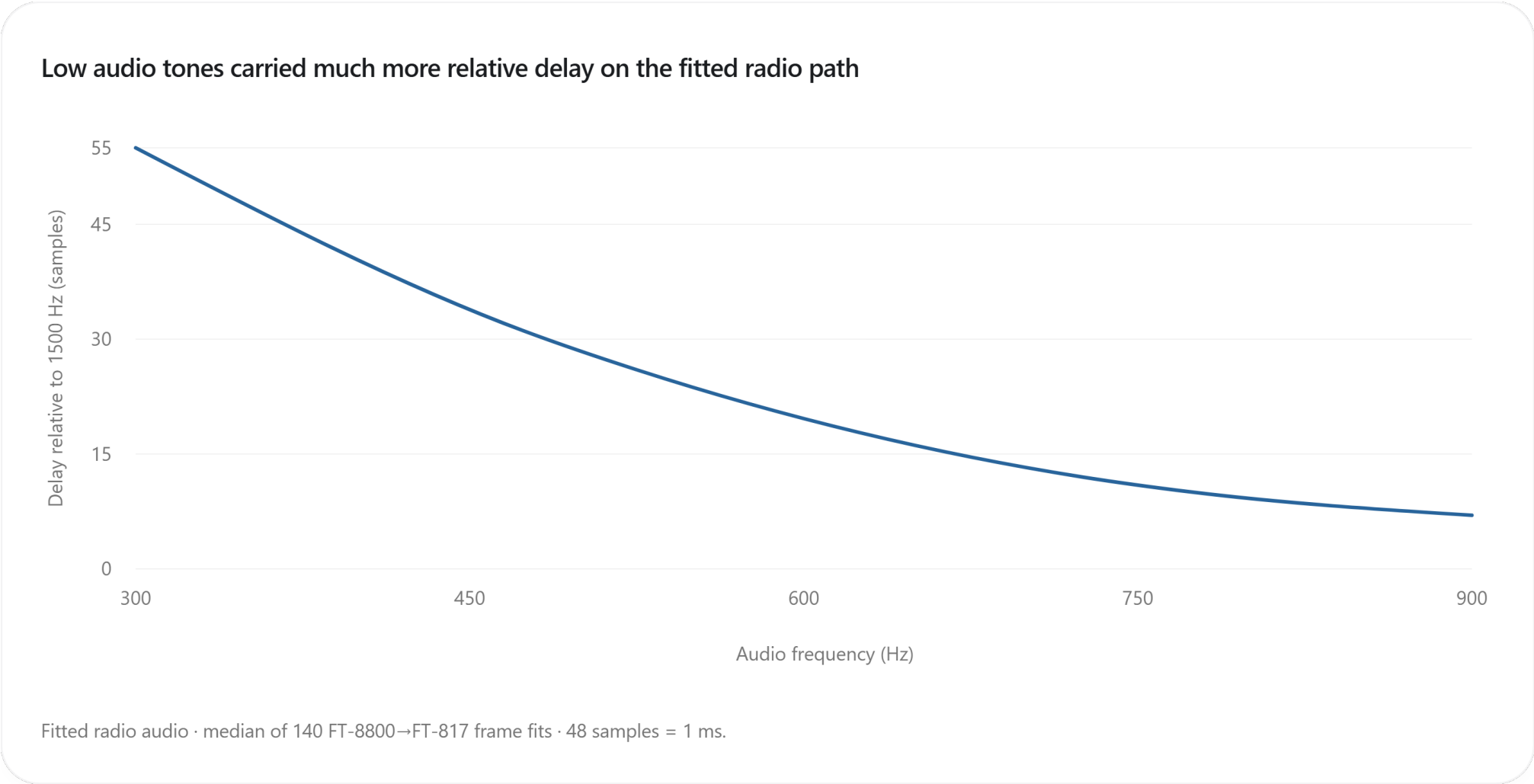


Figure 9. Reviewed source note S25. Full methods and linked sources appear in the appendix.

FIGURE 10 / 7. THE RETONE COMPARISON HAD TO USE THE REPAIRED RECEIVER

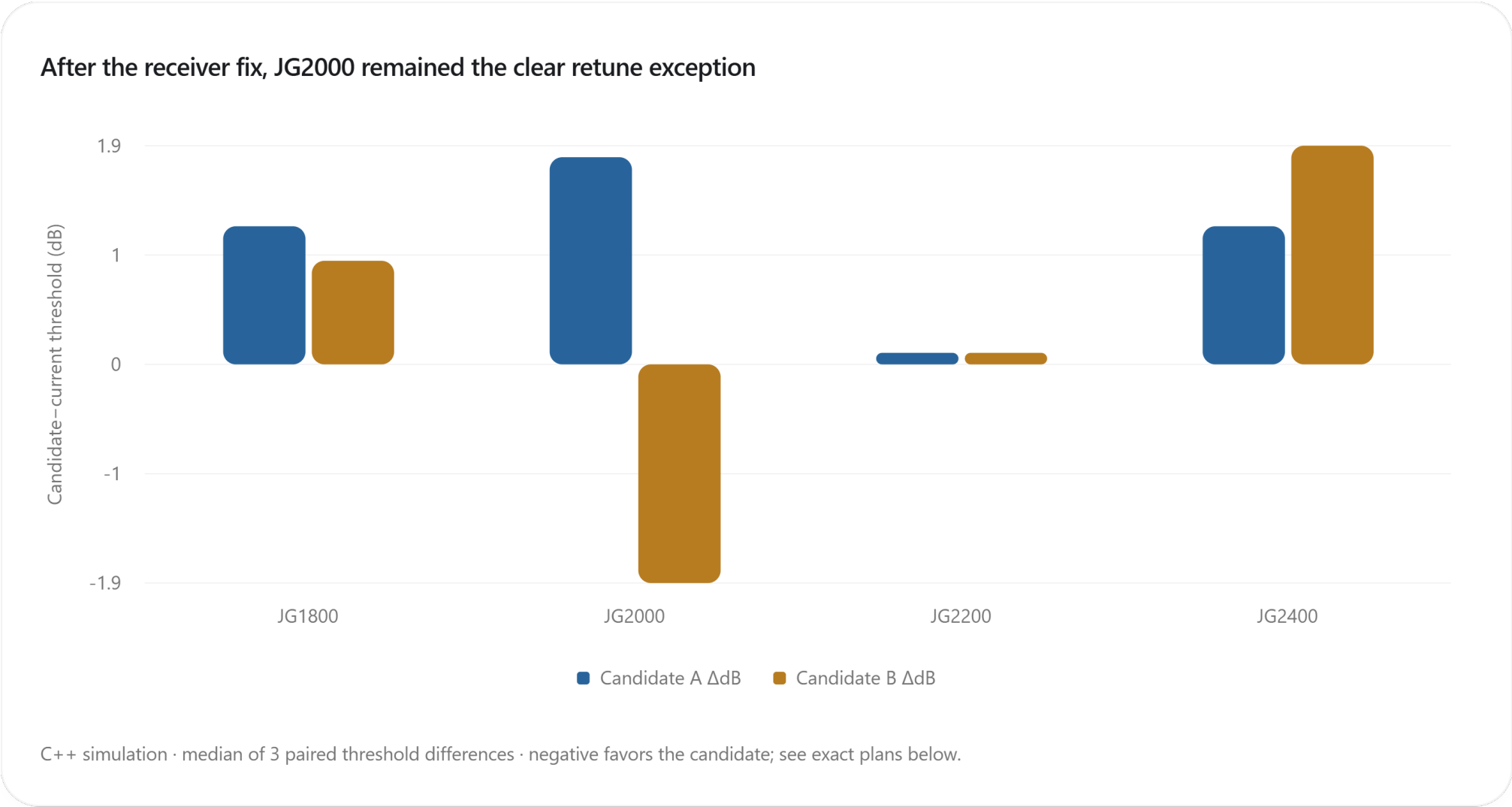


Figure 10. Reviewed source note S16. Full methods and linked sources appear in the appendix.

Table 11. 90%-delivery thresholds with the fixed receiver: lower is better

Mode	Fitted channel	Selected tones (dB)	CandidateA(dB)	CandidateB(dB)
JG1800	WYN fit	9.6	11.1	11.8
JG1800	Median fit	9.5	10.7	10.4
JG1800	Per-frame fits	9.6	9.9	10.0
JG2000	WYN fit	11.9	13.7	10.0
JG2000	Median fit	11.4	13.3	9.7
JG2000	Per-frame fits	11.9	12.9	9.5
JG2200	WYN fit	10.0	10.7	10.4
JG2200	Median fit	9.8	9.9	9.9
JG2200	Per-frame fits	9.9	9.8	10.0
JG2400	WYN fit	13.8	14.4	15.7
JG2400	Median fit	11.8	13.6	13.9
JG2400	Per-frame fits	12.7	13.9	13.8

Reviewed source notes S14. [docs/JG25_INTEGRATION_HISTORY.md](#)

Table 12. The tested four-tone alternatives

Baud	Candidate	Tone centers (Hz)
900	pA	900 / 1350 / 1800 / 2250
900	pB	925 / 1400 / 1875 / 2350
1,000	pA	1000 / 1500 / 2000 / 2500
1,000	pB	700 / 1250 / 1800 / 2350
1,100	pA	650 / 1250 / 1850 / 2450
1,100	pB	700 / 1300 / 1900 / 2500
1,200	pA	750 / 1325 / 1950 / 2600
1,200	pB	700 / 1350 / 2000 / 2650

Reviewed source notes S15. [docs/JG25_INTEGRATION_HISTORY.md](#)

The graph shows the median of three paired differences from the exact table; negative means the candidate needs less signal. At JG1800 and JG2400, both candidates lost on every fitted-channel threshold. JG2200 was effectively close, with no decisive improvement established by these rounded figures.

JG2000 candidate B - 700/1250/1800/2350 Hz - was better: 9.5-10.0 dB versus 11.4-11.9 dB for the selected plan. It also won 30 cells and lost none under the original packet-difference criterion. The owner kept the receiver-only fix and deferred this wire-incompatible retune pending field validation. Retaining a usable deployed format was a practical choice; claiming the current JG2000 tones were the numerical winner would be wrong.

The fixed receiver improved a 3,640-packet C++ channel suite from 2,897 to 3,640 deliveries and a 700-condition RF-audio/added-noise suite from 317 to 662. Those are different populations, not a pooled success rate. The physical high-pass/de-emphasis/harmonic mechanism at the remote WYN station was still inferred; its missing higher-mode receive recording prevented direct confirmation. [Integration §§8.4-8.6](#).

8. The selected default favors speed; the family supplies robustness

The later deterministic reference corpus provides the cleanest comparable matrix: production C++ transmitters and receivers, matched payloads and noise seeds, seven FM channel models, and 90%-delivery SNR thresholds. These are simulations with measured channel fits - not RF sensitivity measurements.

At 256 bytes, JG2400/F0 carries 1,881 bit/s over its complete waveform versus 926 for AX1200. Its seven-channel median threshold was 6.75 dB versus 7.64 dB for AX1200. That small median difference is not enough to establish a general sensitivity win: the corpus itself cautions against strong conclusions from differences below about 0.5-1 dB.

FIGURE 11 / 8. THE SELECTED DEFAULT FAVORS SPEED; THE FAMILY SUPPLIES ROBUSTNESS

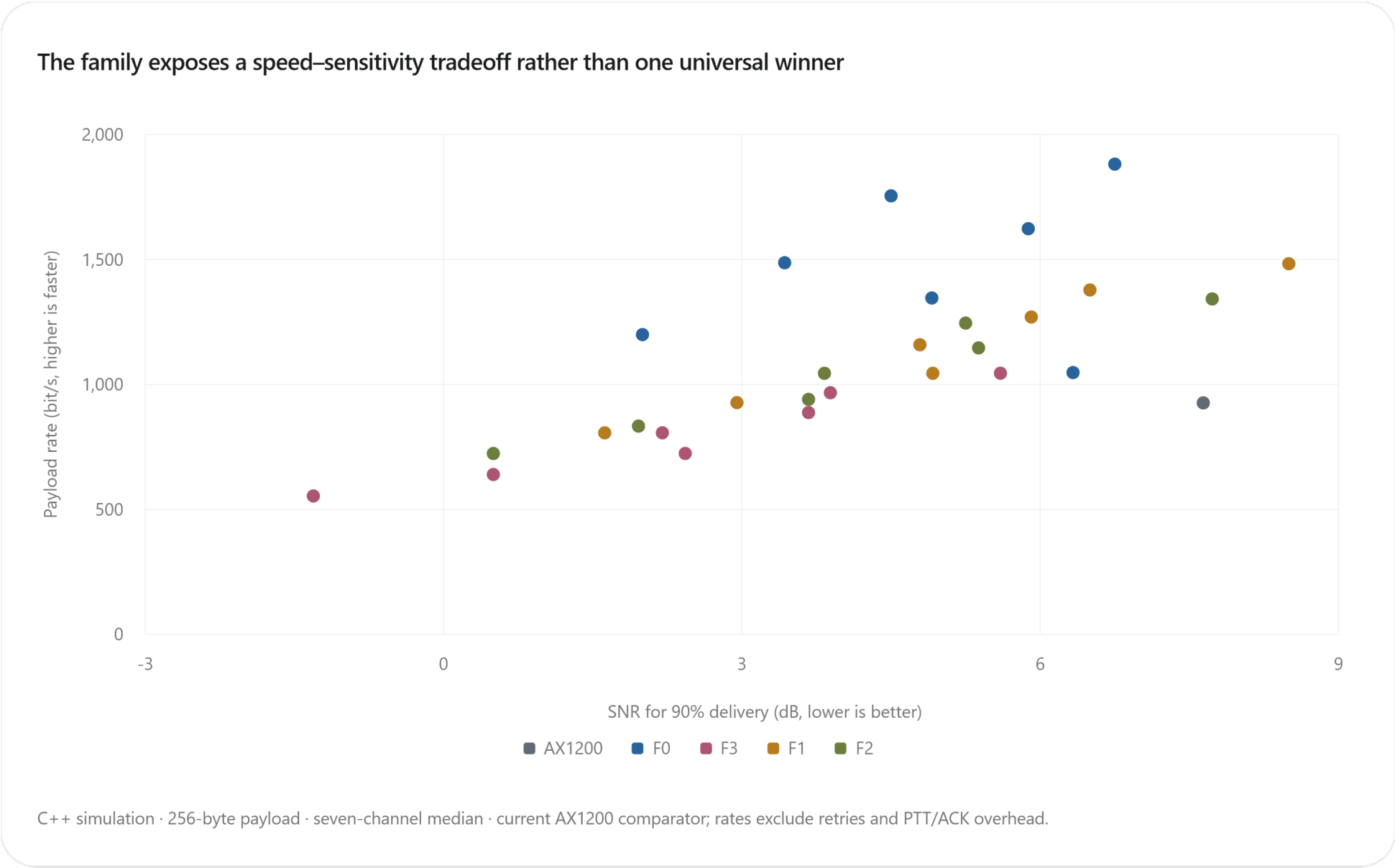


Figure 11. Reviewed source note S18. Full methods and linked sources appear in the appendix.

Table 13. All 28 profiles: 90%-delivery SNR, median over seven channels, 256 B

Mode	F0(dB)	F1(dB)	F2(dB)	F3(dB)
JG1200	6.33	1.62	0.50	-1.31
JG1400	2.00	2.95	1.96	0.50
JG1600	4.91	4.92	3.67	2.43
JG1800	3.43	4.79	3.83	2.20
JG2000	5.88	5.91	5.38	3.67
JG2200	4.50	6.50	5.25	3.89
JG2400	6.75	8.50	7.73	5.60

Reviewed source notes S19. [fixtures/modem_comparison_2026-09/reference/thresholds.csv](#) · [fixtures/modem_comparison_2026-09/reference/f12/thresholds.csv](#) · [fixtures/modem_comparison_2026-09/README.md](#)

Table 14. The same profiles: complete-waveform payload rate

Mode	F0(bit/s)	F1(bit/s)	F2(bit/s)	F3(bit/s)
JG1200	1,047.4	806.2	723.6	553.7
JG1400	1,199.3	927.1	833.3	639.6
JG1600	1,345.7	1,044.5	940.2	723.8
JG1800	1,486.8	1,158.7	1,044.5	806.4
JG2000	1,622.9	1,269.7	1,146.1	887.4
JG2200	1,754.4	1,377.8	1,245.3	966.8
JG2400	1,881.3	1,482.9	1,342.0	1,044.8

Reviewed source notes S19. [fixtures/modem_comparison_2026-09/reference/thresholds.csv](#) · [fixtures/modem_comparison_2026-09/reference/f12/thresholds.csv](#) · [fixtures/modem_comparison_2026-09/README.md](#)

F3 has the lowest threshold at every speed. F1 never improves the rounded 256-byte median above JG1200; F2 offers smaller, mixed benefits. JG2400/F3 drops from 1,881 to 1,045 bit/s while lowering the median threshold from 6.75 to 5.60 dB. For stronger robustness, slower F3 modes go further: JG1200/F3 was about -1.3 dB at 554 bit/s.

These waveform rates include acquisition, header, CRC and coding; they exclude PTT setup, turnarounds, acknowledgments, retransmissions and application envelopes. They are not measured file-transfer goodput. The F0 speed ladder is non-monotonic with this receiver, so “slower is always more sensitive” is not supported either.

9. Realistic channel fits prevent an overbroad victory claim

The seven-channel median hides channel-specific costs. On the WYN-fit, median-fit and per-frame-fit models, JG2400/F0 required about 3.4-3.9 dB more signal than AX1200 at 256 bytes. JG2400/F3 closed much of that gap, at lower payload rate. JG1400/F0 and the slower F3 profiles occupied different useful parts of the tradeoff.

The proper conclusion is that JG25 offered a wider operating menu and a much faster strong-link default - not that every JG profile outperformed AX1200 on every radio path.

FIGURE 12 / 9. REALISTIC CHANNEL FITS PREVENT AN OVERBROAD VICTORY CLAIM

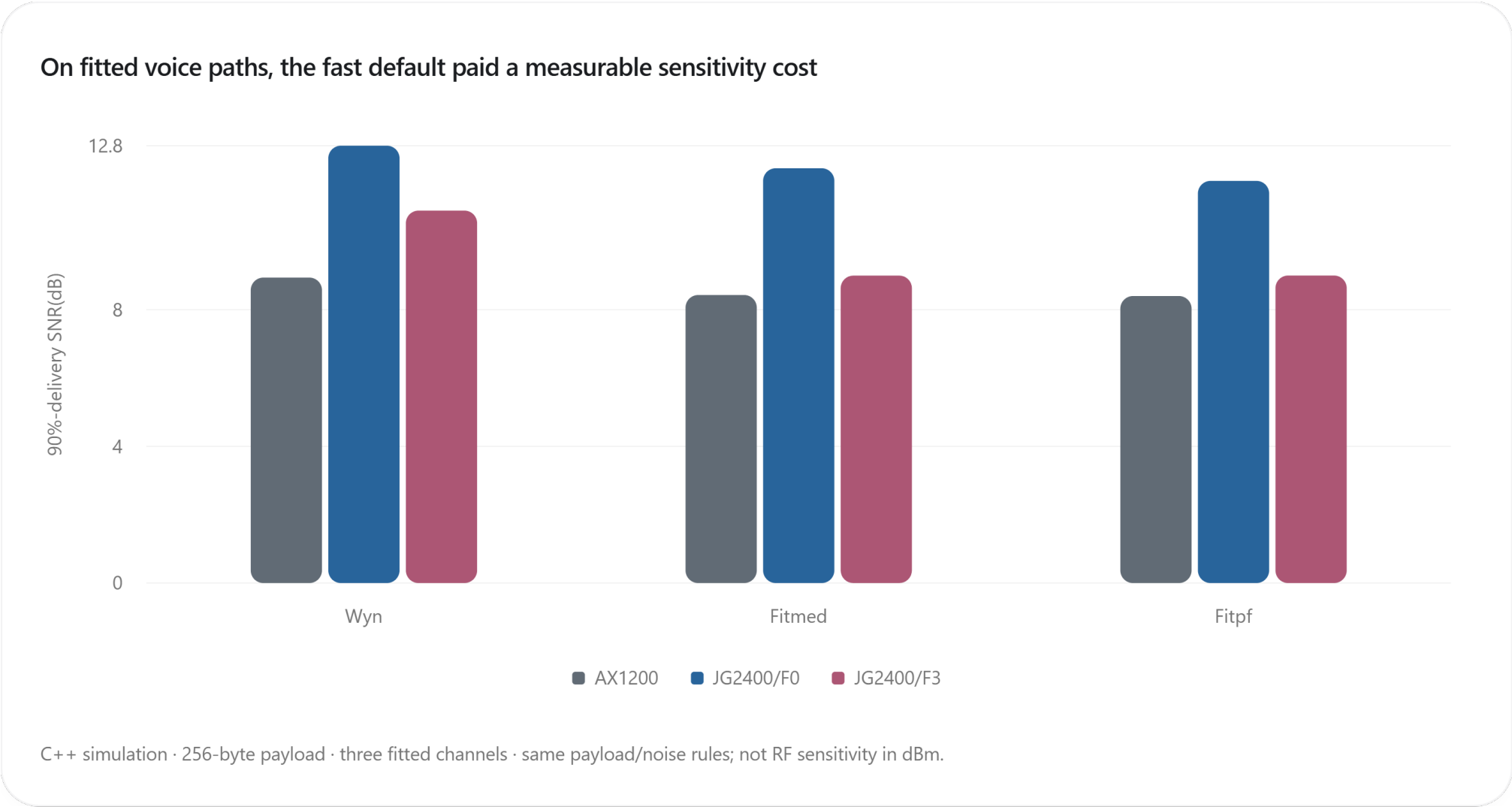


Figure 12. Reviewed source note S20. Full methods and linked sources appear in the appendix.

Table 15. Fitted-channel thresholds, 256 B payload

Channel	AX1200(dB)	JG2400/F0(dB)	JG2400/F3(dB)
wyn	8.94	12.80	10.90
fitmed	8.43	12.14	9.00
fitpf	8.40	11.77	9.00

Reviewed source notes S20. [fixtures/modem_comparison_2026-09/reference/thresholds.csv](#) · [fixtures/modem_comparison_2026-09/README.md](#)

The reference comparison used FM-shaped noise measured in 300-3000 Hz after the channel, with a discriminator-point exception for the double-de-emphasis model. Its reference channels did **not** include the measured transmit third harmonic. Each 90% crossing was interpolated from finite packet samples; the initial 336 curves used 40 or 60 packets at the 90% bracket. F1/F2 were added in a later 98-curve sweep. CPU deadlines can also affect marginal recovery. [Corpus definitions and limits](#).

10. What the selection evidence actually justifies

The central achievement was a coordinated waveform and receiver: four continuous-phase tones, mode-specific symbol geometry, a slow self-describing protected header, nested acquisition options, selectable redundancy and a receiver that learned to preserve phase and compensate channel memory.

The selected constants were not all proved uniquely optimal. Most tone vectors have an identifiable search origin; the final JG2200/JG2400 transitions remain undocumented, and the promising JG2000 retune remains unresolved. The four-versus-higher-tone experiment still has no recovered numerical record. Those gaps should remain visible rather than be filled with reconstructed certainty.

The evidence nevertheless explains why the design survived repeated challenges. Before changing the transmitted format, controlled replays showed large recoverable receiver losses. After those were fixed, most retune candidates no longer improved the tested channels. JG2400/F0 then delivered roughly twice AX1200's complete-waveform payload rate, while the family retained F3 and slower choices for lower-SNR operation.

Table 16. Final decision ledger

Design element	Selected specifics	Why it stayed	Evidence
Modulation	Continuous-phase, four-tone FSK	Two coded bits/symbol; Gray 00 / 01 / 11 / 10	Prototype + radio validation
Rate family	600-1200 baud; 1200-2400 raw coded bit/s	Seven steps balance sensitivity and airtime; number is not baud	Search + code constants
Tone plans	550 / 600 / 650 / 700 Hz adjacent spacing	Keep separation while fitting ordinary radio audio	Search; two origin changes still missing
Acquisition	600 baud; 500 / 1100 / 1700 / 2300 Hz	Known waveform allows detection, offset estimation and training	Chat simulations + implementation
Preamble and sync	NORMAL 48 or ROBUST 96; sync 20 symbols	ROBUST adds 80 ms; both accepted by receive	Chat simulations; mismatched-RX fix
Universal header	350 baud; 950 / 1350 / 1750 / 2150 Hz	16 information bits + CRC-16; K=7 encoder → 76 bits / 38 symbols	Header contest
Body integrity	CRC-32C; six FEC termination bits when coded	CRC remains delivery gate, including recovery paths	Specification + implementation
FEC / interleaving	F0-F3; 8-row header, 32-row coded body	Airtime versus delivered data; F3 strongest later	Simulation + reference corpus
Conditioning	Minimum-phase branches 0,+3,+4,+5,+6,+8 dB/oct	Invert radio tilt without leaving the same dispersion	Matched-magnitude RF replay
Recovery	Continuous synchronizer; phase-aware decode; preamble FIR	Address lost timing, nonorthogonal tones and channel memory	Radio replay + C++ models
Audio / transmit	48 kHz internal; native amplitude0.80; VOX1500Hz leader	Keep geometry reproducible and key audio-triggered interfaces	Implementation; VAC validation
Default	JG2400/F0	Prioritize fast clean-link delivery; F3 for robustness	Owner choice, supported within measured scope

Reviewed source notes S21. [docs/JG25 DESIGN HISTORY.md](#) · [docs/JG25 DESIGN HISTORY ADDENDUM.md](#) · [docs/JG25 INTEGRATION HISTORY.md](#) · [modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

Review corrections and unresolved questions

The expanded branch is substantially more informative, but several statements need qualification or correction. The report uses primary reference tables where they disagree with the narrative. The source issues are identified here; the underlying historical documents retain their original wording.

The most useful remaining experiment is a paired over-air comparison of selected JG2000 versus 700/1250/1800/2350 Hz, with the same receiver, payloads, power and saved audio at both ends. That could resolve the one clear retune exception. Recovering the original greater-than-four-tone notebook or full chat is the separate task needed to justify the remembered tone-count comparison.

Table 17. Issues found during this review

Topic	Source issue	Treatment in this report
Tone count	The decision ledger says no >4-tone test exists.	No completed >4-tone experiment was recovered; that is not proof none occurred. Attribute the owner's recollection.
JG1920 arithmetic	Addendum §5 says 80 bit/s above JG1800.	1920 - 1800 = 120 bit/s; 1920 is 80 below 2000. The redundancy argument survives.
First BER comparison	Addendum §1 quotes 1.30 / 4.27% beside a table showing 1.17 / 5.27125% at -4 dB.	These are different prototype runs. This report keeps each source table separate.
AX1200 paired results	Integration §9.3 reverses the current and 1.0.2 percentages.	Reference summary: at 8 dB current 94.3%, old 15.0%; at 6 dB current 50.7%, old 4.2%.
Baud and mode names	Integration §4 heading refers to 2400 baud for JG2400.	JG2400 is 1200 baud; JG1200 is 600 baud. Use profile constants.
Tone-search verdict	Candidates only helped without the receiver fix is incomplete.	JG2000 pB still wins all three fitted-channel threshold comparisons. It was deferred, not disproved.
Airtime cost	A relayed 38% F3 airtime increase lacks a comparable denominator.	At 256 B: $1881.3 / 1044.8 - 1 \approx 80\%$ more waveform duration for F3. Do not reuse 38% for that comparison.
Radio scope	662/700 RF packets can suggest 700 fresh transmissions.	The 700 conditions combine saved radio audio with clean and synthetically added-noise replay.
JG1200 phase exclusion	A phase-validation sentence says excluded at 1200 baud.	Interpret as JG1200 mode (600 baud). The original phase target, JG2400, is 1200 baud.

Reviewed source notes S23. [docs/JG25 DESIGN HISTORY ADDENDUM.md](#) · [docs/JG25 INTEGRATION HISTORY.md](#) · [fixtures/modem_comparison_2026-09/README.md](#) · [modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#) · [docs/JG25 PHASE TRELLIS VALIDATION.md](#) · [AX1200 paired reference summary](#)

Evidence and reproducibility

This report reviews branch snapshot [1cd39dea4441](#), retrieved 23 October 2026. No radio trials or sensitivity sweeps were rerun. Tables and graphs are transcribed or explicitly derived from the branch's historical evidence.

- [Original waveform history](#): early spacing, header, interleaving and radio-replay results.
- [Recovered design addendum](#): original prototype tables and tone-search lineage.
- [Integration and field history](#): receiver controls, failed alternatives, final retone comparison and owner decisions.
- [Profile constants](#): baud, exact tone vectors, preamble, sync and header constants.
- [Phase validation](#): independent transmit-truth matching, repeated-target limits and recovery budgets.
- [Reference F0/F3 CSV](#) and [F1/F2 CSV](#): per-channel delivery thresholds and burst rates. Medians in this report are recalculated from these rows.
- [Corpus methods](#) and [throughput method](#): channel models, SNR convention, packet counts and rate definitions.

The source notes appendix preserves the scope, methods and links attached to the reviewed graphs and tables. Early sample-domain BER experiments and later in-band 90%-delivery thresholds are intentionally kept separate. One radio pair underlies most fits; WYN targets repeat two objects. Small perfect runs show feasibility, not universal reliability.

Source notes and methods

These notes carry over the report's reviewed provenance. S-numbers above identify each query's scope and original source links. Repeated uses of the same reviewed rows point to the same note. Early BER simulations, saved-radio replays and later modeled delivery thresholds use different populations and SNR conventions.

S1 · awgn

Chat simulation, Addendum §2. 550/1250/1950/2650 Hz; 30,000 symbols per point; sample-domain AWGN SNR. Independent tone-energy detector, perfect timing.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](docs/JG25_DESIGN_HISTORY_ADDENDUM.md)

S2 · spacing

Chat simulation, History §1. 1200 baud, -2 dB sample-domain SNR. A finite spacing sweep, not an eight-tone comparison.

[docs/JG25_DESIGN_HISTORY.md](docs/JG25_DESIGN_HISTORY.md)

S3 · voice

Chat simulation, Addendum §3. -2 dB sample SNR; original 550/1250/1950/2650-Hz 4-FSK plans. Filtering, compression, residual timing/frequency error. 18,000 symbols ×3 runs per point.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](docs/JG25_DESIGN_HISTORY_ADDENDUM.md)

S4 · modes

Shipped FM profile constants and recovered origins. Raw mode number is coded bits/s; baud = raw/2. Tone-center span excludes spectral skirts.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

S5 · family

Chat simulation, Addendum §5. SNR at 1% uncoded BER, typical/narrow paths. Early optimized vectors; JG2200 and JG2400 differ from shipped plans. Not modern 90%-delivery thresholds.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

S6 · header

Chat simulation, isolated protected-header comparison. Same 32 encoder-input bits plus six tail bits. Airtimes calculated from coded symbols/ baud and rounded to 0.1 ms; -8...-4 dB is prototype sample SNR.

[docs/JG25_DESIGN_HISTORY.md](#)

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

S7 · preamble

Chat simulation, Addendum §7: complete acquisition under bursty colored interference. NORMAL 48 and ROBUST 96 preamble symbols; sync20, header38. Small model-specific run; no confidence intervals supplied.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

S8 · interleave

Chat simulation, direct waveform/filter/soft-decoder chain; finite Monte Carlo cells, no supplied confidence intervals. A zero is zero errors observed in that run.

[docs/JG25_DESIGN_HISTORY.md](#)

S9 · fec

Coding definitions: rates nominal, termination/CRC overhead excluded. Modern role comes from the fixed-receiver 256-B comparison, not the early binary-AWGN abstraction.

[docs/JG25_DESIGN_HISTORY.md](#)

[docs/JG25_INTEGRATION_HISTORY.md](#)

[fixtures/modem_comparison_2026-09/README.md](#)

S10 · emphasis

Real-radio replay, Aug18 FT-8800→FT-817. Same recordings before/after audio-domain emphasis; n differs by profile; zero errors in a small sample is not universal reliability.

[docs/history/jg25-evidence/2026-08-18-adaptive-emphasis.md](#)

S11 · phaseFilter

Integration §2 and commit 37652fb: pinned-branch replay of 36 frames. +6 phase realizations have magnitude error <0.01 dB; +7.5 also changes magnitude. Do not attribute the last two extra frames solely to phase.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S12 · phaseRecovery

Sept2 recording analyzed Sept3. Header-valid JG2400 bodies: 18 failures recovered and 21 controls retained, byte-exact. Includes 11 long-body failures; this is recorded RF replay.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S13 · lateEq

Integration §8.6 final receiver-only design. Populations differ and are not pooled. WYN 27 denotes incoming valid decodes, 12 targets repeat two transfer objects; not independent trials. 700 includes clean replay and added synthetic noise, not 700 fresh transmissions.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S14 · toneRetest

Integration §8.5: fixed receiver, long F0 frames, simulated fitted channels, SNR at90% delivery. Candidate labels are specific to each baud. Positive candidate-minus-current dB means more signal required (worse).

[docs/JG25_INTEGRATION_HISTORY.md](#)

S15 · toneCandidates

Exact candidate identities for the patched-receiver threshold comparison. These are four-tone alternatives, not different tone counts.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S16 · toneDelta

Derived median of three paired SNR-threshold differences per baud, using Integration §8.5 rounded inputs. Candidate minus current; negative is better. Not a confidence interval or an independent combined trial.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S17 · thresholdCells

Reference C++ simulation, 300-3000-Hz in-band FM-shaped noise; source CSV cells. 90% crossing interpolated; bracket n40 or60, not a measured RF sensitivity. F0/F3 Sept26; F1/F2 Oct20. No TX third harmonic in these reference channels.

[fixtures/modem_comparison_2026-09/reference/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/reference/f12/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/README.md](#)

S18 · tradeoff

Derived seven-channel medians at256 B from threshold CSVs. SNR threshold lower is better; payload bit/s= $8 \times 256 / \text{burst_s}$, before retries/PTT/ACK/application overhead. Median of seven thresholds is not a population delivery guarantee.

[fixtures/modem_comparison_2026-09/reference/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/reference/f12/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/README.md](#)

S19 · fecMatrix

Same seven-channel median,256-byte payload. Modern receiver; F1/F2 code robustness includes actual soft metrics and recovery policy, not coding gain in an idealized binary-AWGN decoder.

[fixtures/modem_comparison_2026-09/reference/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/reference/f12/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/README.md](#)

S20 · channelComparison

Three fitted channel models at256 B. WYN fit uses only its preamble; fitmed and fitpf come from FT-8800→FT-817. Simulation after fitting, not new RF threshold measurements.

[fixtures/modem_comparison_2026-09/reference/thresholds.csv](#)

[fixtures/modem_comparison_2026-09/README.md](#)

S21 · design

Design-selection ledger assembled from pinned sources. Some current runtime defaults were chosen later than the original waveform. Amplitude is not an RF power calibration.

[docs/JG25_DESIGN_HISTORY.md](#)

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[docs/JG25_INTEGRATION_HISTORY.md](#)

[modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

S22 · chronology

Historical sequence. A record of tests and decisions, not a time-series performance comparison.

[docs/JG25_DESIGN_HISTORY.md](#)

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[docs/JG25_INTEGRATION_HISTORY.md](#)

S23 · reviewNotes

Review observations checked against the source tables and profile constants. Corrections apply to this report only; the source branch was not edited.

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[docs/JG25_INTEGRATION_HISTORY.md](#)

[fixtures/modem_comparison_2026-09/README.md](#)

[modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

[docs/JG25_PHASE_TRELLIS_VALIDATION.md](#)

[AX1200 paired reference summary](#)

S24 · parameters

Exact header geometry and prototype pre-body timing. Excludes PTT leader/tail, VOX leader, body and application envelope.

[docs/JG25_DESIGN_HISTORY.md](#)

[docs/JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[modem/jg25/include/openfsq/jg25/jg25_profile.hpp](#)

S25 · delay

Integration §8.4: raw group delay relative to 1500Hz, median of 140 fitted FT-8800→FT-817 frames. Values rounded in historical account; radio mechanism at WYN remains inferred.

[docs/JG25_INTEGRATION_HISTORY.md](#)

S26 · alternatives

Alternative modulation and tone-count evidence inventory; no invented performance values.

Discussion is not completed measurement; absence of a recovered record does not prove no experiment occurred.

[JG25_DESIGN_HISTORY.md](#)

[JG25_DESIGN_HISTORY_ADDENDUM.md](#)

[JG25_INTEGRATION_HISTORY.md](#)