



WHITE PAPER

5G-AI-ALE

Automatic Link Establishment as a layer of the SafecomLink protocol

How SafecomLink turns the beacons every station is already sending into a channel memory, and how the decision engine uses that memory to pick the frequency most likely to link.

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1. Executive summary

ALE operators know the drill. A scan list, a sounding schedule, an LQA table, and a controller that calls the other station on whichever channel scored best. It works, and it has worked since the 1980s. It also needs its own modem, its own waveform, its own air time for soundings, and a link that ends the moment you want to change channel.

SafecomLink 5G-AI-ALE takes the same idea and builds it out of parts the SafecomLink protocol already has. The beacons and general calls that every station transmits are the soundings. The station activity database that every station keeps is the LQA table. The frequency scanner that already steps the radio through a channel list is the scan engine. The modem connect handshake is the link call. 5G-AI-ALE adds one thing on top: a decision engine that reads that history for a specific station, ranks the channels by evidence, and drives the connect sequence through them until one answers.

Because it is a layer of the protocol and not a separate box, it costs no extra air time, no extra hardware, and no change of behavior for the stations you are calling. A station that has never heard of 5G-AI-ALE still gets linked correctly, because from its side the call is an ordinary SafecomLink connect on a frequency it is listening on.

This paper describes what the engine takes into account when it chooses a channel, what it refuses to do, how the link sequence runs, and how the same engine watches an established link and proposes a move before it fails. It is written for people who run ALE today and want to know exactly where this is the same and where it is different.

A note on scope. This paper covers a subset of the elements and of the decision-making process, and it simplifies what it does cover so that it can be read quickly. The production engine takes in more signals than are described here, weighs them in more ways, and adapts as it runs. What follows is enough to understand how it behaves, not a specification of how it is built.

2. Where classic ALE stops

Second generation (2G) ALE (MIL-STD-188-141 / FED-STD-1045) solved channel selection with three mechanisms. Every station scans a shared list of channels. Stations sound on those channels at intervals so others can score them. Each station keeps a link quality analysis matrix, and when you call, the controller works down that matrix from best to worst. Third generation (3G) ALE tightened the timing with synchronous dwell groups and added faster handshakes, but the architecture is the same.

Four things follow from that architecture, and every ALE operator has lived with them.

- **The sounding is overhead.** It carries no traffic. On a busy network, sounding schedules eat a real share of the channel.
- **The LQA is a separate table.** It lives inside the ALE controller. The operator sees a score, rarely the observations behind it.

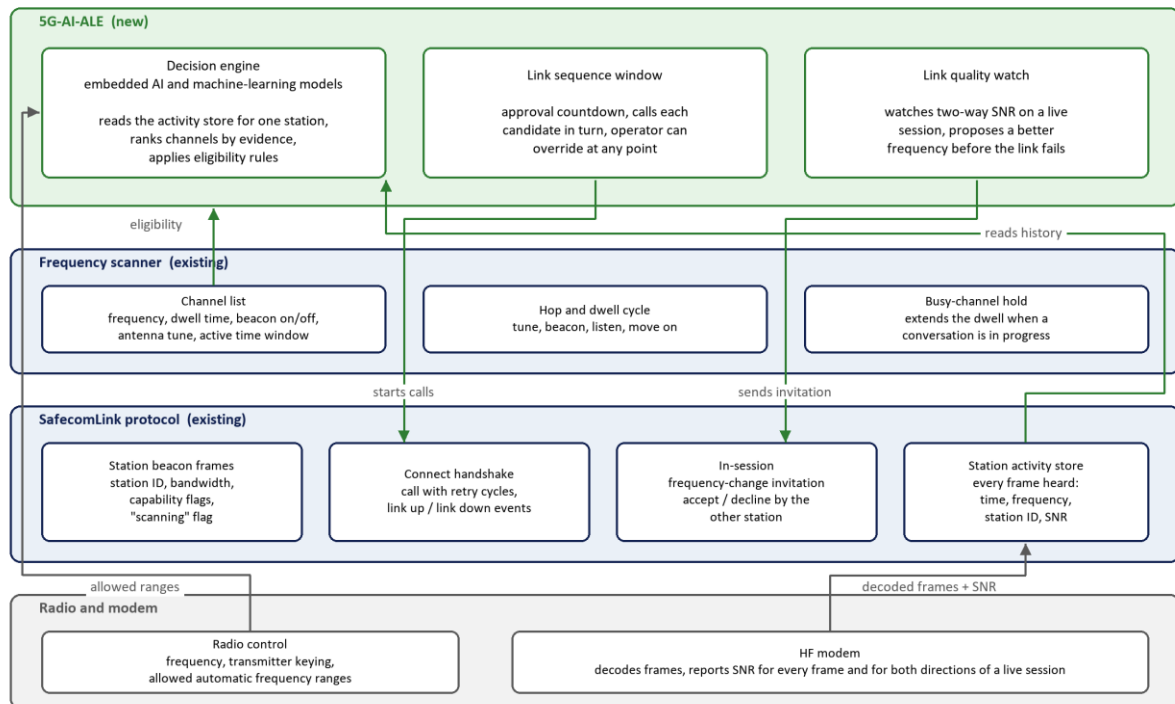
- **The controller is a separate radio function.** ALE picks the channel, then hands off to whatever data modem carries the traffic. Two waveforms, two state machines, two places for things to go wrong.
- **The link is the end of the decision.** Once linked, ALE is out of the loop. If the channel goes bad ten minutes later, you drop the link and start again.

None of this is a criticism of the standard. It is a description of the boundary 5G-AI-ALE was built to cross.

3. Design principle: a layer, not a bolt-on

The SafecomLink protocol already carries almost everything an ALE controller needs. 5G-AI-ALE was designed as a consumer of those existing signals rather than as a parallel system with its own frames. Figure 1 shows the layering, and the table after it maps the classic building blocks to what SafecomLink uses instead.

Figure 1. 5G-AI-ALE as a layer on top of the existing SafecomLink protocol



Classic ALE element	SafecomLink equivalent	What changes for the operator
Sounding transmission	The station beacon and the general calls that stations already send on every scan channel	No dedicated sounding. Beacons carry the station identifier, bandwidth and a "scanning" flag, so they are useful traffic in their own right.
LQA matrix	The station activity database: every frame heard, with frequency, SNR, time and station identifier, kept for the long term	Same data feeds the station activity panel and 5G-AI-ALE. One record, two uses.

Classic ALE element	SafecomLink equivalent	What changes for the operator
Scan list and dwell	The frequency scanner list: channel, dwell time, beacon on/off, antenna tune on/off, time window	Same list already used by the SafecomLink scanner mode. ALE mode is the third state of the same frequency scheduler mechanism.
Selective call and handshake	The modem connect handshake, with its own retry cycles	One waveform for the call and the traffic. No hand-off between modems.
Channel selection logic	The 5G-AI-ALE decision engine	New. Described in section 6.
In-link channel change	The SafecomLink frequency-change invitation, sent inside the live session	New use of an existing protocol message. The link is not dropped to move.

The consequence of this design is worth stating plainly. 5G-AI-ALE never puts a frame on the air that a non-ALE SafecomLink station would not understand. Every transmission it triggers is a beacon, a connect request or a frequency-change invitation, all of which have been in the protocol for years. The intelligence sits entirely on the calling side, in how it reads what it has heard and in how it sequences the calls.

4. The data layer: beacons as soundings

Every SafecomLink station that hears a beacon, a general call or a ping writes a record to its local station activity store (shown in the application as the Last Heard panel). The record is small and it is the whole basis for the decision engine, so it is worth knowing what is in it.

Field	Content	Role in 5G-AI-ALE
Time (UTC)	When the frame was decoded	Recency tiers and hour-of-day matching
Frequency	The radio's frequency at the moment of decode, as reported by radio control	The candidate channel itself
Station identifier	The station that transmitted	History is kept per station, not per channel
SNR (dB)	Signal-to-noise ratio reported by the HF modem for that frame	The quality score.
Frame type	Beacon, general call, ping and others	All types count as evidence that the path was open
Band, bandwidth, location, flags	Metadata carried in the beacon	Displayed to the operator; the scanning flag tells you the other side is stepping through channels

Two properties of this data matter for how the engine behaves.

It is per station. Classic LQA scores a channel. 5G-AI-ALE scores a channel for a given station. A 7 MHz channel that is excellent to a station 300 km away is often useless to one 3000 km away at the same hour. The engine never mixes them.

It only knows what it heard. If your station was tuned elsewhere when the other side beamed, there is no record. This is exactly why ALE mode keeps the scanner running: dwelling on every channel in the list is how the history gets filled. A station that sits on one frequency all day will have a rich history for that frequency and nothing else, and the engine will say so rather than guess.

5. The scan layer

5G-AI-ALE runs on top of the existing frequency scanner. Selecting ALE on the schedule button puts the scanner into its normal cycle with **one difference: connect requests are intercepted and routed through the decision engine instead of going straight to the modem.**

The scanner list carries, per entry, the frequency, the dwell time in seconds, whether to send a beacon while on it, whether to fire the antenna tuner on arrival, and an optional UTC time window during which the entry is active. The cycle is simple. Tune to the entry, tune the antenna if asked, beacon if asked and if the beacon interval has elapsed for that entry, dwell, move on. If the busy detector fires while dwelling, the hold is extended by the configured busy hold time so a conversation in progress is not talked over.

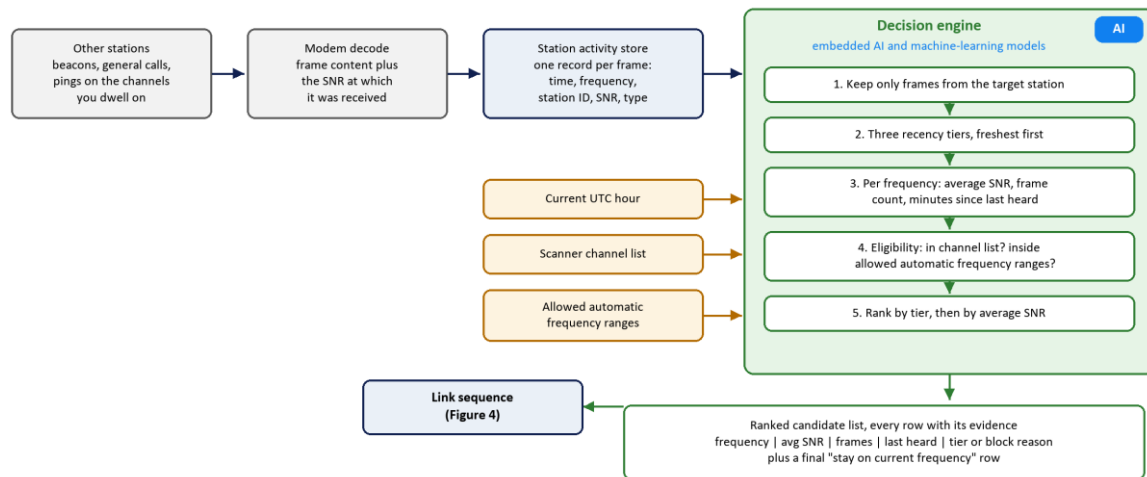
The beacon sent from a scanning station carries a scanning flag. Other stations show it as an icon in their activity panel with the note that the station is stepping through channels and a connect may take longer. This is the protocol telling the caller what to expect, and it is one reason the sequence in section 7 tries more than once per channel.

The scanner pauses itself whenever the station is doing something that must not be interrupted: a link in progress, a connect attempt, a beacon on the air, an incoming ping, a relay notification, an antenna tune, or a 5G-AI-ALE sequence. When the sequence ends without a link, the scanner resumes from where it was.

6. The decision engine

This is the part that carries the AI in the name, so it deserves a precise description. The engine is not a black box and it does not hallucinate. It uses embedded AI and machine-learning models for the decision making. In simplified terms, those models read the activity store for one station, groups what it finds by frequency, weighs the groups by how recent and how relevant they are, and hands back a ranked list where every row shows the evidence behind it. Figure 2 shows a simplified path from a frame on the air to a ranked row. The steps in the figure are the ones an operator can see in the window. Further weighting happens inside the models and is outside the scope of this paper.

Figure 2. From frames on the air to a ranked candidate list (simplified view)



6.1 Inputs

When you ask to connect to a station, the engine is called with the target station and, optionally, a frequency to exclude (used during an established link so the current channel is not proposed as an alternative). It reads four things:

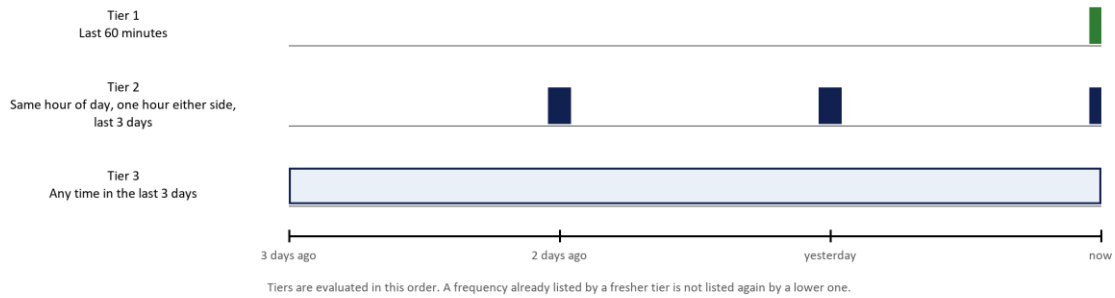
- The activity records for that station, with frequency, SNR and timestamp.
- The current UTC hour.
- The frequency scanner list, which defines the channels this station is willing to sit on.
- The allowed automatic frequency ranges from radio control, which define where this station is permitted to retune itself without a human, and whether it may cross into another band to do so.

6.2 Three tiers of recency

HF propagation has two clocks. There is the short one, where a channel that worked twenty minutes ago is very likely to work now. And there is the daily one, where a channel that worked at this hour yesterday and the day before is a good bet today even if you have not heard the station since. The engine models both with three lookups, run in order, freshest first (Figure 3). This is the simplified view. The three tiers are the backbone of the recency weighting. The models add further weighting on top of them, and that part is deliberately left out of this paper.

Tier	Window	Reasoning
1. Recent	The last 60 minutes (configurable), any hour	The path is open right now. Strongest evidence there is.
2. Same hour	The last 3 days (configurable), only frames heard within one hour either side of the current UTC hour	Daily propagation cycle. The ionosphere at 14:00 UTC today behaves much as it did at 14:00 UTC yesterday.
3. Any time	The last 3 days, any hour	Fallback. Weaker, but a channel that has carried this station at all beats one that never has.

Figure 3. The three recency tiers over a 3-day history (defaults shown)



Within each tier the records are grouped by frequency and, per frequency, the engine computes the average SNR, the number of frames heard, and the time since the last one. Frequencies are ordered by average SNR, best first. A frequency that already appeared in a fresher tier is skipped when a lower tier finds it again, so the final list is tier-ordered first and SNR-ordered inside each tier. Every candidate keeps a label saying which tier produced it. The operator sees "Last 60 min" or "Same hour, last 3 days" next to the frequency and can judge for themselves how much to trust it.

Averaging over multiple frames rather than taking the last one is deliberate. One strong beacon during a short enhancement should not outrank a channel that has delivered a steady -8 dB for three days. The frame count is shown alongside the average for the same reason. Five frames at -12 dB is a better bet than one frame at -6.

6.3 Eligibility rules

Ranking is only half of the decision. A channel can be the best path in the world and still be one this station must not use. The engine applies two hard rules and, rather than silently dropping a channel that fails them, it keeps the row and marks it blocked with the reason.

- **Not in the scanner list.** If the frequency is not one of the channels this station scans, it is not a channel this station will call on. The scanner list is the operator's statement of intent about where the station lives.
- **Outside the allowed frequency ranges.** Radio control carries a list of frequency ranges the software may retune to on its own, plus a switch for whether it may change band. A channel outside those ranges, or on another band when band changes are not allowed, is blocked. This is the same guard that protects every other automatic frequency change in SafecomLink, and 5G-AI-ALE does not get an exception to it.

Blocked rows stay visible, greyed out. This matters more than it sounds. When the engine proposes 7.1 MHz and the operator can see that 14.1 MHz had a better average but is greyed as outside the allowed range, the operator knows what to change in the configuration, and knows the engine did not simply miss it.

6.4 The fallback row

The candidate list always ends with one extra row: stay on the current frequency. It is the last thing the sequence tries and it means 5G-AI-ALE can never do worse than a plain connect. If the history is

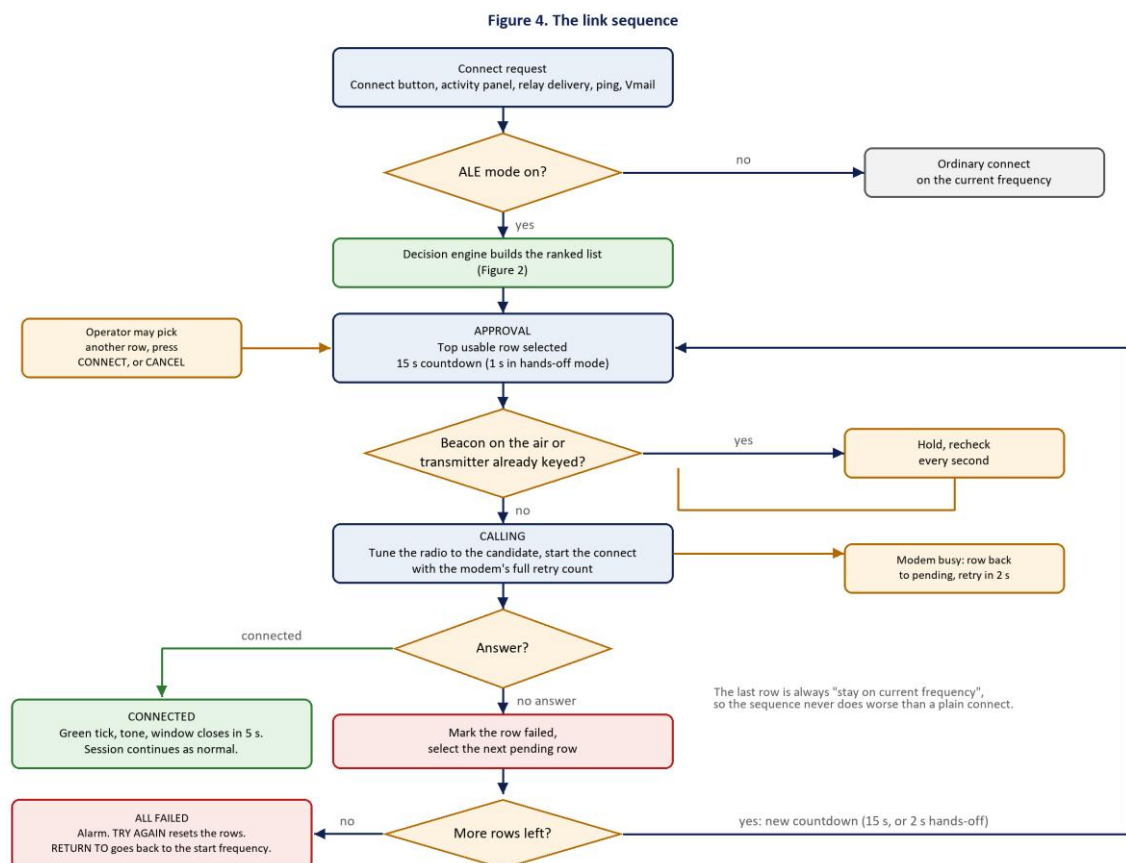
empty for a station, the window says so, and the only row is that one. The engine does not invent a recommendation from nothing.

6.5 What the engine does not do

It does not transmit anything to make its decision. It does not consult external propagation predictions, because those describe a typical path and the activity store describes this path. It does not learn across stations; a good channel to station A says nothing about station B. And it does not override the operator. A recommendation with a countdown is still a recommendation, and clicking any other row stops the clock.

7. The link sequence

With ALE mode on, every route into a connect goes through the sequence: the Connect button, a click on a station in the activity panel, a relay notification that needs delivery, a ping, a Vmail with a station to reach. The usual band check is skipped, since the engine is now the one choosing the band. What opens instead is the 5G-AI-ALE window. Figure 4 shows the full flow.



7.1 Approval

The window shows the ranked candidates with their status, frequency, color-coded average SNR, frame count, age of the last frame, and basis or block reason. The top usable row is selected and the status line reads "ALE recommends 7.105 MHz. Connecting in 15s". The operator can let it run, click

CONNECT to go now, click another row to take over (which stops the countdown), or cancel. A configuration switch reduces the countdown to one second for stations that want hands-off operation.

7.2 Calling

On the countdown reaching zero, or on CONNECT, the sequence tunes the radio to the candidate and starts an ordinary modem connect. The status line shows attempt number, channel, and which call cycle of the modem's retry count is on the air. A timeline on the right logs every step with a UTC timestamp. Three protections apply before the first transmission.

- If a beacon is on the air or the transmitter is already on, the sequence holds and rechecks every second. It never transmits over its own beacon.
- If the modem is busy and the connect thread did not start, the row goes back to pending and the sequence retries after two seconds.
- If transmitting is disabled in the software, nothing goes on the air and the window reports it.

7.3 Outcomes

The modem reports back into the window through the same events that drive the rest of SafecomLink. There is no polling and no guesswork about what the modem is doing.

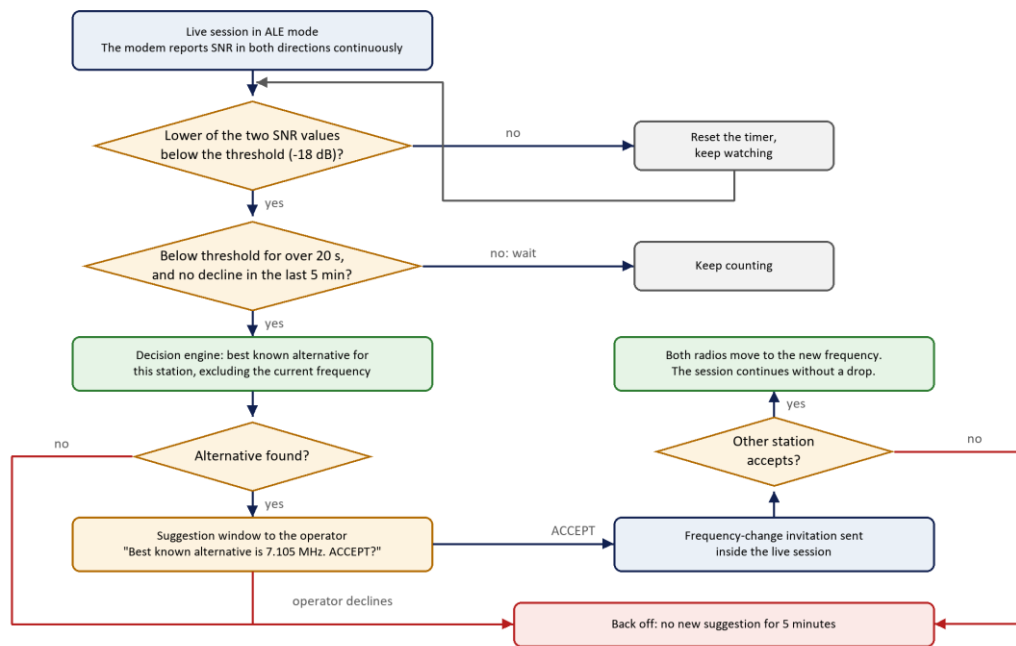
- **Connected.** The row gets a green tick, a tone plays, and the window closes after five seconds. The link continues as any other SafecomLink session.
- **No answer.** The row gets a red cross, the next pending row is selected, and a new countdown starts (15 seconds, or 2 in hands-off mode). Attempts continue down the list and end on the stay-here row.
- **All failed.** An alarm sounds. The window offers TRY AGAIN, which resets all rows to pending, and RETURN TO followed by the frequency you started on.
- **Operator switch.** Clicking a different row while a call is running aborts the current attempt and, once the modem has settled, starts on the chosen row. Cancel during a call aborts and stops.

Throughout the sequence the beacon thread is paused and the scanner is paused. When the window closes without a link, both resume. When it closes with a link, they stay paused for the duration of the session as they normally would.

8. Watching the link: quality-driven frequency change

Classic ALE leaves the loop the moment the link is up. 5G-AI-ALE stays in it. While a modem link is running in ALE mode, the software already receives a continuous SNR report in both directions: what the other station reports hearing from you, and what you are hearing from them. The engine watches the lower of the two (Figure 5).

Figure 5. Link quality watch on a live session



If that value stays below the configured threshold (default -18 dB) for more than 20 seconds, the engine asks the same candidate lookup as before for the best known alternative for this station, excluding the current frequency. If it finds one, a small window opens: "Link quality is deteriorating. Best known alternative for STATION-B is 7.105 MHz. Click ACCEPT to send a frequency-change invitation."

ACCEPT does not drop the link. It queues a standard SafecomLink frequency-change invitation inside the live session, exactly the one an operator would send by hand. The other station gets the usual accept-or-decline prompt. If they accept, both radios move and the link continues on the new channel. If the operator declines the suggestion, or the other side declines the invitation, the engine backs off for five minutes before it will suggest again. If there is no better channel in the history it also backs off, rather than nagging with nothing to offer.

This is the piece that a bolt-on ALE cannot do, because it depends on the ALE logic and the traffic modem being the same state machine.

10. Notes for ALE operators

If you run a MIL-STD ALE network today, the following is what changes in practice.

Put beacons on your scan channels. The history is built from what stations hear. A network whose stations beacon on each scan channel builds a full matrix within a few hours. A network whose stations run silent has nothing for the engine to work with, and every call falls through to the stay-here row.

Share the same scanner list. This is the equivalent of a common ALE channel group. The engine blocks channels that are not in the local list, so a station calling on a channel the other side does not scan will not link, exactly as in classic ALE.

Set the allowed frequency ranges honestly. They exist so the software never retunes the radio somewhere the operator would not. If you want the engine to move between 7 MHz and 14 MHz on its own, the cross-band permission must be on and both ranges must be listed.

Expect the countdown. The 15 second approval is there so an operator who is watching can override. Stations that are unattended should enable the skip switch.

Dwell times matter twice. They set how long you listen on each channel, which is how you fill the history, and they set how long the other side is away from any one channel, which is why the sequence uses the modem's full retry count on each attempt before moving on.

There is no interoperability with MIL-STD ALE. 5G-AI-ALE links SafecomLink stations to SafecomLink stations. It does not decode or emit 2G or 3G ALE waveforms.