**Abstract**

During World-War-2, the entomologist P.S.Callahan noticed a remarkable similarity: — The shapes of the various radar aerials closely resembled the various spines etc. on insects. From 1965 onwards, he promoted the idea that insects often detect pheromones via infra-red as a scaled-down equivalent of those radar microwaves — with the pheromone-molecules acting as transponders or sites of fluorescence (all invisible to us). This notion was supposedly demolished in a 1977 debate within a single issue of the *International Journal of Insect Morphology and Embryology*.

However a recent detailed review of that debate ([www.wbabin.net/physics/trail17](http://www.wbabin.net/physics/trail17)) has shown up the logic-flaws on both sides of that contest, and hence come to new conclusions based on the same experimental evidence:

1. That the evidence does support Callahan’s main thesis involving infra-red “beacons”.
2. That it is vital to distinguish between long-range effects (>100 yards, for which there is no credible alternative mechanism anyhow), and short range (where orthodox olfaction is a confounding factor).
3. A new interpretation of an anomaly within Callahan’s sets of results, suggests that insect brains may sometimes process infra-red signals directly via dielectric paths (thus *bypassing the expected action-potentials!* That could be much more efficient, and might help to explain the surprising memory capacity of bees etc.
4. It is a matter of public concern that significant interdisciplinary work like Callahan’s should be so promptly dismissed on inadequate grounds — even if his own presentation had its failings. Was it all too technical and therefore threatening, or what?

If infra-red signal patterns really do have such pheromone and kairomone roles, that may open up new possibilities for non-chemical arthropod control.
1940s: P.S. Callahan noticed — (during W W 2):

#1 [✓] Radar-aerials have various odd shapes — which closely resemble the spines etc. on insects! (In fact he later claimed this is true for all 15 types of dielectric aerial!) This strongly suggests a similar role:

\[ \text{Nature} \approx \text{Human-Design} \]

1960: E.R. Laithwaite (a Professor of Engineering):

#2 \[ \text{Q: Many } \checkmark \text{ moths were known to be locating mates miles away.} \]

But how?

#3 [✓] Laithwaite showed there are at least 2 quite different navigation methods:

(i) Short range = orthodox olfaction (uncertain direction, chasing pheromone itself).

(ii) Long-range (>“100 yards”) \[ \rightarrow \text{ Clearcut direction, even if wind stops all pheromone from reaching } \checkmark \] — so there must be a separate extra mechanism.

#4 [✓] L. concluded that the long-range effect must depend on infra-red (IR) signals.

But problematic features:

#5 \[ \text{Q: In } \checkmark , \text{ which organ might receive such IR signals?} \]

#6 [✓] L. assumed such reception would be via the antennae.

#7 [✓] If antennae are the receivers, then their size implies long IR wavelengths (>20 \( \mu \text{m} \))

#8 \[ \text{Q: What is it about the } \varphi \text{ that generates the following signals:} \]

(i) “I’m receptive”, and then

(ii) “Sorry, you’re too late!”

— transmitted too quickly for any diffusion explanation via carrier-molecules!

#9 [✓] L. assumed the signals were emitted from the \( \varphi \)’s body (as if IR glow-worms), and perhaps independent from pheromone emission.

#10 [✓] L. overlooked the possibility of fluorescence from pheromones (even though he did discuss attractant fluorescence from water drops — in a rather different context, as an aside!). Cf. #15.
1967-1977: Callahan (an Entomologist, then at USDA)

#11[✓] C. welcomed Laithwaite’s support for infra-red (IR).

#12[✓] Invoking his WW2 spines etc. (#1 above), C. increased the list of receiver-options beyond Laithwaite’s one-off antenna-suggestion (#6).

#13[✓] These alternative smaller aerials implied shorter IR wavelengths (1-20 µm) — more useful.

#14[✓] C. showed that the actual spine-lengths tallied only with those IR wavelengths which can travel through the air (without being absorbed by it).

#15[✓] C. amply demonstrated fluorescence-generated IR, and moths’ attraction to it.

#16[✓] C. argued that the energy-input for this fluorescence came from abundant ambient radiation of higher frequencies — even at night. Of course UV gives a particularly strong effect with its high frequency.

#17[✓] C. argued the case for “stimulated emission” (Einstein 1917, Townes 1965) as adding to the fluorescence (and as a weak gesture towards laser-like activity). [Useful but perhaps non-essential.]

#18[✓] He also argued that, as the frequency generated collectively by stimulated emission will depend on pheromone concentration, this is therefore a means for detecting gradients.

But problematic features:

#19[X] He quite overlooked Laithwaite’s Long/Short-Range distinction (#3)! — So he tried to impose his IR ideas onto all-or-most Short-Range effects. Not totally unreasonable, but on shaky ground — and irrelevant to the Long-Range case.

#20[X] He saw the stimulated-emission gradient (#18) as the key navigational mechanism — despite Laithwaite’s convincing argument against gradients for Long-Range. Indeed C. even asserted that L.’s experimental evidence must be wrong!!

#21[X] C. made several “amateurish” mistakes in his physics details, (e.g. units, terminology, etc…), not critical in themselves, but prejudicial to his case.

#22[?] Anomalous finding: C’s experiments showed behavioural response to IR, but he was unable to find any intervening action-potential in the nerves! (And yet there was no such problem for visible light!) — Also see #32 below, and the “conclusions”.

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The Basic Logical Solution to the Cited Experimental Findings:

- Male spines receive IR directional cues for that species
- Such IR is transmitted through the atmosphere, though certain frequencies are blocked by absorption
- This IR is emitted from pheromone molecules, which fluoresce using energy from ambient shorter waves
- Energy from ambient radiation of various higher frequencies

[Also some unknown signal promptly tells still-remote male latecomers to save their energy “Sorry, you’re too late” (#8).]

Some possible enhancements to that basic solution:

#23 Arrays of spines etc. Callahan pointed to the need for whole arrays of aerials (as in Radio-Astronomy), especially for enhancing direction-finding and image-formation. Clearly the spines on insects are available as arrays.

#24 The “Sorry, you’re too late” message (#8) may be a separate “anti-pheromone” molecule-type and its IR emissions. — Or:

#25 This information may come from the shape of the IR image if it can be “seen” in 2D. Thus:

Possible infra-red 2D image of pheromone “cloud” from ♀ before-and-after mating

- in still air (“bullseye model”):
  - diffusing pheromone molecules
  - horizon
  - ♀ just after mating hence gap in 2D image
- and with a cross-wind:
  - diffusing pheromone molecules

*Post-conference critique about “cancellation” of the pheromone signal:*

If we see this prompt cancellation-effect as mysterious, it is probably because we are still assuming a key role for diffusion — that very slow process — at least in setting up an identifiable “cloud shape” (#25 above), or perhaps as something more orthodox. However, if fluorescence is the main mechanism, this will probably be occurring mainly where the pheromone-cloud is most concentrated — very close to its ♀ source (though not actually at the source herself as Laithwaite assumed). Hence when the female stops emitting the pheromone, that local high-concentration will fairly quickly disperse, and the most effective part of the IR-emission would also cease. Thus the above suggestions #24 and #25 are probably both superfluous, though they might still offer contributory cues for some species.
The 1977 debate between Diesendorf and Callahan:

This debate was a mess; with political point-scoring, and no editorial.

Callahan’s shortcomings (incl. #19-#22) were paraded, while his-and-Laithwaite’s achievements were brushed aside: so he was deemed to have lost the “battle”. Hence the whole idea of IR communication was dropped, despite the unresolved issues.

#26[X] Neither C nor D mentioned Laithwaite’s distinction between Short and Long Range!!!!

#27[X] So both got bogged down on Short-Range issues: — (arcane unresolved topics such as: signal-chopping, \( d < \lambda \) in bipole theory, and orthodox olfaction-mechanisms — all being of dubious relevance).

#28[X] Both wasted effort discussing unlikely alternative energy sources (such as “rubbing”, and “black-body radiation”).

#29[X] Both wasted effort discussing possible optical-coherence of the signals (probably irrelevant!) — largely because Callahan tended to confuse “coherence” with the vital “monochronicity”!!!!

#30[X] Likewise they argued unproductively because Callahan had not made it clear what he meant by “maser-like”. Was he concerned with production of: 
   ➔ Coherence? (irrelevant, #29)? — or —
   ➔ Amplification? (non-basic, #17)? — or —
   ➔ Gradient-measure? (Short-range, and not necessarily basic, #18)?
And with no efficient reflectors, the effect could only be relatively weak anyhow.

#31[?] D objected that thermal-IR background would drown those signals with wavelengths > 4 \( \mu \)m; but that need not apply fully if the signals were narrow-band and “loud” enough.

#32[?] Anomaly of the missing action-potential (#22) after IR stimulation, while still getting a behavioural response. — Diesendorf saw this as a fatal flaw! Callahan didn’t! One logical resolution is to postulate a different extra peri-neural transmission-mode — see the “Conclusions”.

Further information, including extra references:

http://www.ondwelle.com/OSM03.pdf (This topic);
http://www.ondwelle.com (Related works);
http://www.ondwelle.com/OSM12.pdf (History of the whole project)

Amendment of detail (10 April 2014):
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Conclusions:

♣ Laithwaite was right in believing there are at least two odour-detecting mechanisms, and that the one for Long-Range involves infra-red.

♣ Callahan was right in identifying many insect sensillae as the aerials for infra-red signals; but he exposed himself to criticism by careless presentation, and inadequate self-defence.

♣ Diesendorf identified some of Callahan’s failings, but overlooked the possibility of important truths hidden under the confusion. He also virtually ignored Laithwaite.

There are three plausible explanations for the mysteriously rapid “anti-pheromone” (“too late”) signal:
(i) a hypothetical “antidote” system;  
(ii) the promptly altered “bullseye-or-wedge” geometry of the IR-emitting pheromone-cloud;  
(iii) most of the effective fluorescence will occur fairly close to the female, and hence will soon dissipate when she stops producing the pheromone.

The “missing action-potential” (#22, #32) might be explained if we accept that axons sometimes serve as optic fibres for infra-red, as was postulated independently for mammals (Traill, 1978 Part B).

The scientific community was remiss in allowing this topic to be buried prematurely — and that is a matter of some social concern.

This avenue could well open up new possibilities for arthropod-control.

Main References:
Callahan, P.S. (1977a) “Comments on Mark Diesendorf’s critique of my review paper” International J. Insect Morphol. and Embryol. 6(2), 111-122. — “/3/” — part of the debate
Diesendorf, M. (1977a) “Insect sensilla as dielectric aerials for scent detection? Comments on a review by P.S.Callahan” International J. Insect Morphol. and Embryol. 6(2), 105-109. — “/2/” — part of the debate