INNOVATIONS IN ELECTRONIC MONITORING OF STORED-GRAIN INSECTS

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Monitoring of insects is essential in an integrated management system for postharvest commodities. Many alternatives to methyl bromide (and other problematic fumigants and treatments) will only be financially attractive with early warning of infestation problems and elimination of unnecessary "scheduled" insect treatments. Automated monitoring systems involving computer acquisition of data from sensors distributed throughout stored commodities eliminate the need for scheduling costly manual inspections and permits access to realtime data from all storage regions. These data can alert personnel to the need for control measures and can be input directly to expert management decision support systems.

The Electronic Grain Probe Insect Counter (EGPIC) system (patent allowed) was developed to provide automated realtime monitoring of insects by using modified grain probe traps. In general, traps can be very sensitive to low insect densities because they monitor continuously and can be enhanced with chemical attractants. However, traps must be periodically inspected, which is labor intensive, limits the temporal availability of data, and restricts placement to easily accessible locations. The EGPIC system overcomes these limitations by electronically counting insects (across the full range of species' sizes encountered in stored-grain) as they pass through the probe.

In automated monitoring systems, the most challenging component for development is usually the sensing unit. The EGPIC system uses a custom designed sensor head that detects insects as they pass through its projected infrared-beam. In early laboratory tests of the prototype sensor head (Shuman and Coffelt, 1994) shown in figure 1a, it was found that some species (e.g., sawtoothed grain beetles and rice weevils) could grab onto the infrared-beam transducers and produce multiple counts. This was successfully remedied in the laboratory by the inclusion of a clear acetate insert (figure 1b) partially coated (to not obscure the beam) with Teflon. However, field testing (flat storage of corn, Wisconsin, 1993) of the EGPIC system with this sensor head revealed a susceptibility to grain dust adhering to the insert, thus masking the beam and providing a foothold for insects. A second-generation sensor head design (figure 1c) addresses this problem by recessing the infrared-beam transducers back from the narrow downward path (through the top funnel) of dust and insects. Several design features help keep insects from loitering around the infrared-beam. The steepness of the surface (55° from the horizontal) of the top funnel was established based on tests in which all insect species placed on the top edge of the funnel quickly (< 1 min.) fell through. The aperture (3.2 mm) at the bottom of this funnel is made smaller than the beam width (5.1 mm) to insure that falling insects do not miss the beam. The bottom edge of the funnel is positioned 2 mm above the top of the beam so that any insects inadvertently hanging from the bottom of the funnel would not intersect the beam and cause multiple probe counts. The sharp acute angle (35°) of the bottom edge also keeps such insects from crawling around and up the outside surface of the funnel (and then down to the infrared-beam transducers). The function of the lower funnel (also with a sharp acute angle bottom edge) similarly is to prevent insects from crawling up from the bottom of the sensor head to the infrared-beam transducers. The lower funnel's bottom aperture is wide enough (19 mm) so that insects falling through the top funnel pass through without contacting it. The counting accuracy of this sensor head in the laboratory is greater than 95% and preliminary data from a field test currently being conducted (Williston Seed Processors, Williston, FL) do not reveal any problems due to dust or crawling insects.

In the first field test (Wisconsin), grain particles entering through the holes in the probe body originally used (Storgard WB Probe II, Trécé, Inc., Salinas, CA) resulted in high probe count errors. Although grain particles do not lead to false insect data when passive probes are manually inspected, the infrared-beam sensors of the EGPIC electronic probes cannot distinguish between insects and grain particles similar in size. To reduce the number of grain particles entering the probes, a different probe body design (Trappit Insect Probe Trap, AgriSense-BCS Ltd., UK) consisting of an acrylic tube with downward slanted drilled holes for the insects to enter (figure 2A) was selected. By using this body upside down with the holes slanted upward (figure 2B), gravity tends to keep grain particles out while not affecting the entry of insects (Subramanyam et al, 1989). A tubular Mylar outer sleeve covers the holes during insertion of the probe into the grain to prevent particles from entering the probe, after which the sleeve is pulled up.

In large-scale automated monitoring systems, the major cost may not be for the remote sensor hardware but rather for the means of getting the data back into a computer at a central location. The direct approach of an individual cable for each sensor is physically unwieldy and economically impractical when hundreds or thousands of sensors are involved and the computer is thousands of meters away. This is further complicated by the need for all sensors to monitor continuously to insure detection of insect activity, which can be erratic in nature. Continuous monitoring is achieved by each probe's insect counts being accumulated in its own dedicated digital register (counter). The data in each register can be downloaded to the central computer several times a day since changes in insect populations typically occur over days rather than within seconds. To provide a means for reading these registers in a large-scale EGPIC system, the Serial Multiplexing Addressable Register Transmission System (SMARTS - patent pending) was developed (Shuman and Nasah-Lima, 1996) to efficiently transfer insect count data from up to a million EGPIC probe registers to the serial port of a central computer via a spatially distributed multiplexing tree network. An example of this with four levels of multiplexing is shown in figure 3. Data pathways (each a twisted pair of wires using the RS-422 standard) from probe registers (in sensor level modules) are multiplexed (i.e., merged into a single wire pair) as soon as possible, ending with a final single pathway to the computer. Each pathway can be 1200 m long and the final pathway can be any serial data communications medium (e.g., radio link, telephone line, optical fiber, etc.). Each probe register can be randomly accessed by the computer sending addressing data along the same (bidirectional) pathways. In an actual SMARTS implementation, for a given number and spatial distribution of deployed probes, the size (number of inputs) of the multiplexers, the number of multiplexing levels, and the locations of individual multiplexer modules would be established topographically to minimize cost. This would be a function of the total length of cable and the number of multiplexing modules employed.

References

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Shuman, D. and N. Nasah-Lima. 1996. A distributed multiplexing transmission network for acquiring data from spatially divergent sensors. ASAE Paper No. 96-3040. 16 pp. St. Joseph, Mich.: ASAE.

Subramanyam, Bh, P. K. Harein, and L. K. Cutkomp. 1989. Field tests with probe traps for sampling adult insects infesting farm-stored grain. *J. Agric. Entomol.* 6(1):9-21

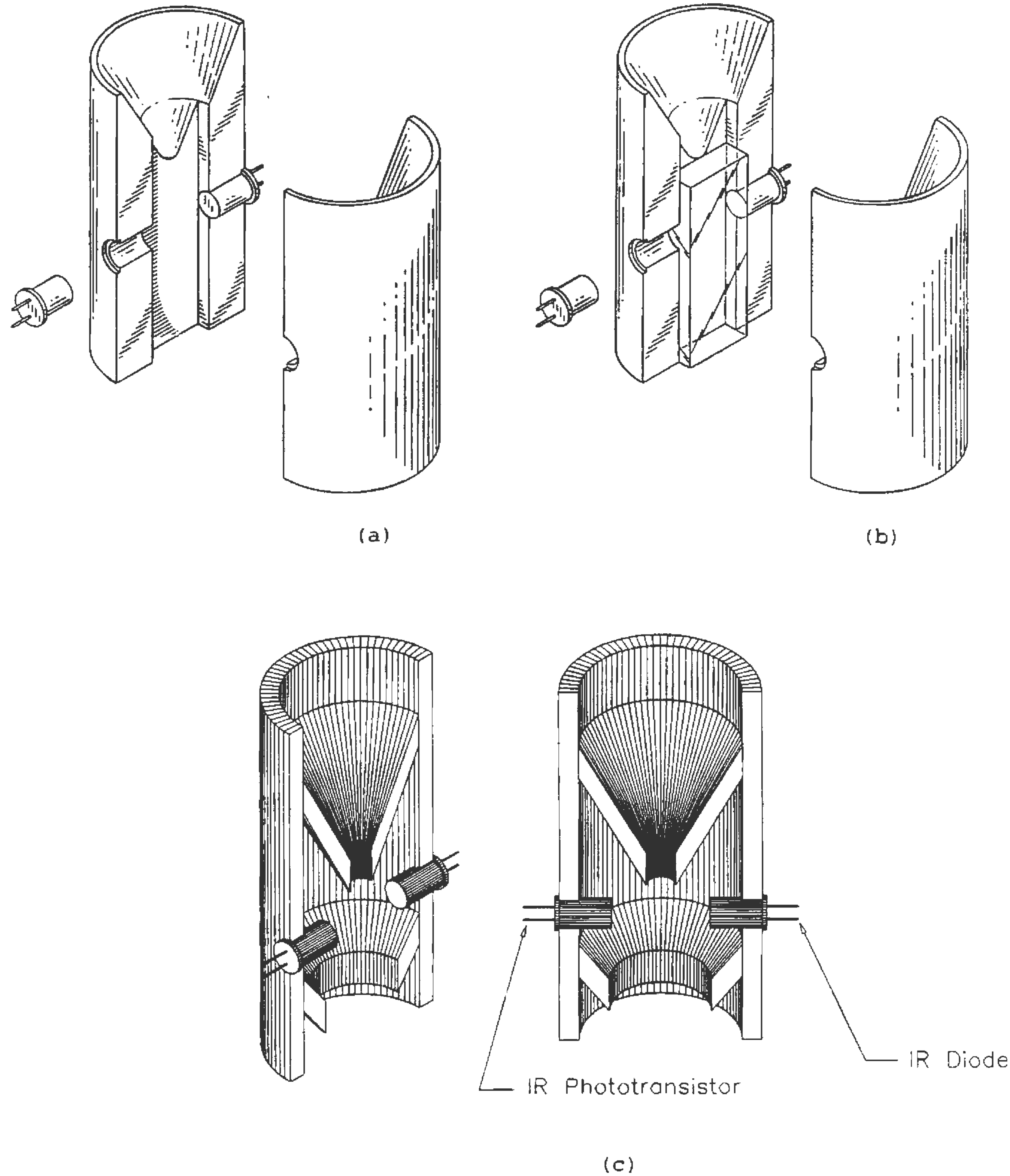

Figure 1- EGPIC Infrared Beam Sensor Head Designs Evolution. (a) Prototype moulded resin design. (b) Inclusion of clear insert. (c) Second-generation machined PVC design.

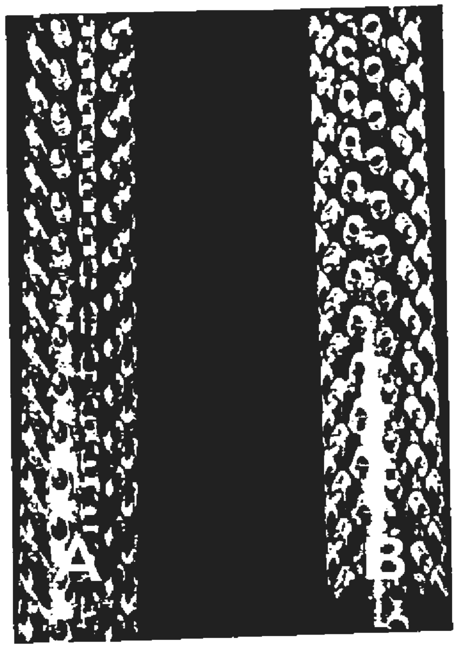

Figure 2 - Probe Bodies with (A)drilled holes slanted as intended by manufacturer and (B)drilled holes reversed slanted for use in EGPIC.

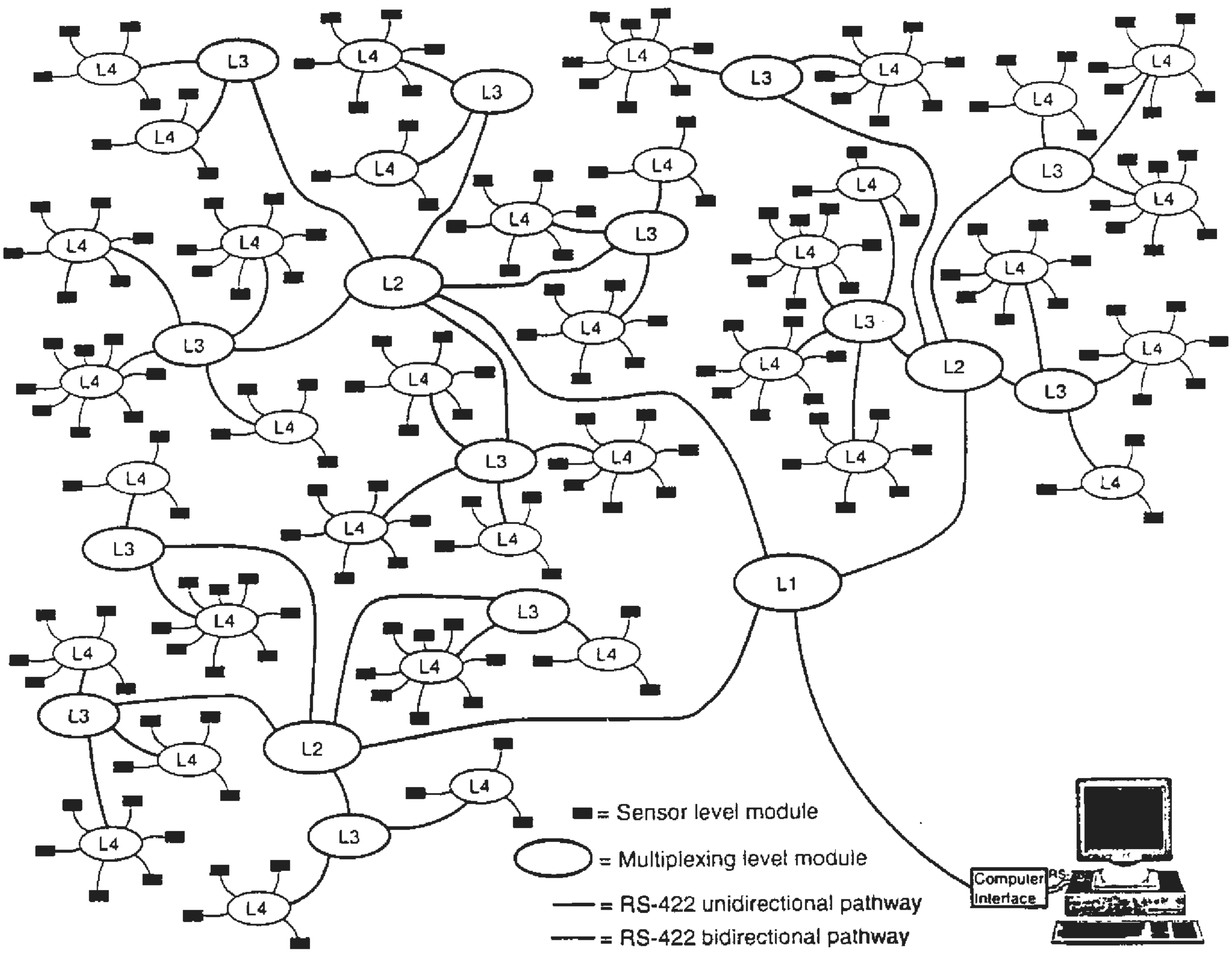

Figure 3- SMARTS Tree Structure Topology Example with 4 Levels of Multiplexing