Diffuse Infrared
Conference Room Tests

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Objectives:

Between late 1990 and mid 1991, Photonics performed a series of tests using prototypes of a diffuse IR wireless networking system. These tests were performed in a particular conference room which was chosen for its difficult IR environment. The room combines stray IR sources from large windows along a South facing wall and multiple incandescent spot lamps that are used to light the room's conference table. Although these IR sources are unusual, we felt that a robust IR system should be able to operate in this environment; the tests were designed collect operating information and to verify performance limitations in the units under test.

The diffuse IR test units were developed to provide LocalTalk[tm] service between computer terminals operating at approximately 230 KBits/second. The actual IR data transmission rate was 920 KBits/second, with the excess bandwidth used to provide forward error correction and control information. The packet error rate measurements were made using the Interpol utility package developed by Apple Computer. Interpol is a network diagnostic tool incorporating an automatic retry mechanism that reports errors only after 16 successive failures of the RTS/CTS protocol. As a result of the forward error correction and automatic retry, the reported packet error rates are normally very small, typically measured in the range of 1 or 2 failures per 100,000 packets.

Procedure:

The tests performed included the following: First, the intensity distribution of IR from the spot lamps was measured at several points on the conference table surface. Based on these data, and the IR background level generated by sunlight penetrating into the room, a mathematical model was constructed that could predict performance of the IR link between two transceivers. These model results were then verified with actual tests. It is important to note that the effects of sunlight, although they appeared to be minimal, could not be accurately measured or repeated from one test run to another.

A floor plan of the conference room, table and lights is shown in Figure 1. The ceiling in this room is at approximately 9 feet above the table top on which the IR transceivers were mounted and is finished with a glossy surface quite unlike the acoustical tile normally found in office buildings.

The spot lamp intensity and distribution patterns were measured with a PIN diode IR detector and a voltmeter reading the average DC generated across a test load. Measurements were restricted to the table top and were made along two axes centered on the illumination pattern from the tested lamps. The distribution, as a function of distance from the center of each spot pattern, is shown in figure 2.

The measured average currents due to the spot lamps were used to calculate the anticipated level of shot noise that would exist within the bandwidth of interest, 2 MHz for the tested transceivers. These shot noise values were input to a math model which calculates the expected signal level in an IR receiver at some distance from a known transmitting source. The model was used to calculate the resulting signal to noise level that would be available at the input to the receiver chain, including noise components from other sources in the system. The resulting model output is shown in Figure 3. These curves indicate the expected signal to noise ratio for a receiver located at a fixed distance from the center of a spot lamp pattern as a function of the distance from the receiver to a standard transmitter.

Results:

The final phase of the test was verification of the model predictions. Previous experience had led us to expect that the receiver would fail at a signal to noise level of 20 dB, and that was borne out in the tests in the conference room. Above the 20 dB level the packet error rate for short packets (60 bytes + overhead) was better than .001%.

Initial test were done with the receiving unit positioned away from any of the spot lamps and 25 feet from the standard transmitter. With the spot lamps off, the IR system operated continuously without errors for a period of 30 minutes.

When the spot lamps were turned on, the packet error rate rose to a perceptible value but was still less than .01%. The explanation for this rise is either interference from the diffuse IR generated by the spot lamps or radiated electrical interference created by the spot lamps. The performance of the IR link was unaffected by the orientation of the transmitter and receiver and did not improve as the units were brought closer together, tending to support the electrical interference argument, but tools that would have confirmed the source were not available. The magnitude of this interference was later found not to be significant relative to the direct interference created by the spot lamps.

The next sequence of tests required that the receiver be moved in several steps toward the center of one of the spot lamp patterns. At each step, the response of the receiver would be measured as the transmitter to receiver distance was varied. We expected to see the maximum range of the system degrade as the interfering IR from the spot lamps increased.

With the receiver 18 inches away from the center of the spot lamp pattern the packet error rates began to rise as the transmitter was reached a point 10 feet from the receiver. The increased packet error rate was in the range of 0.1% to 1%, but a quantitative measure was not made.

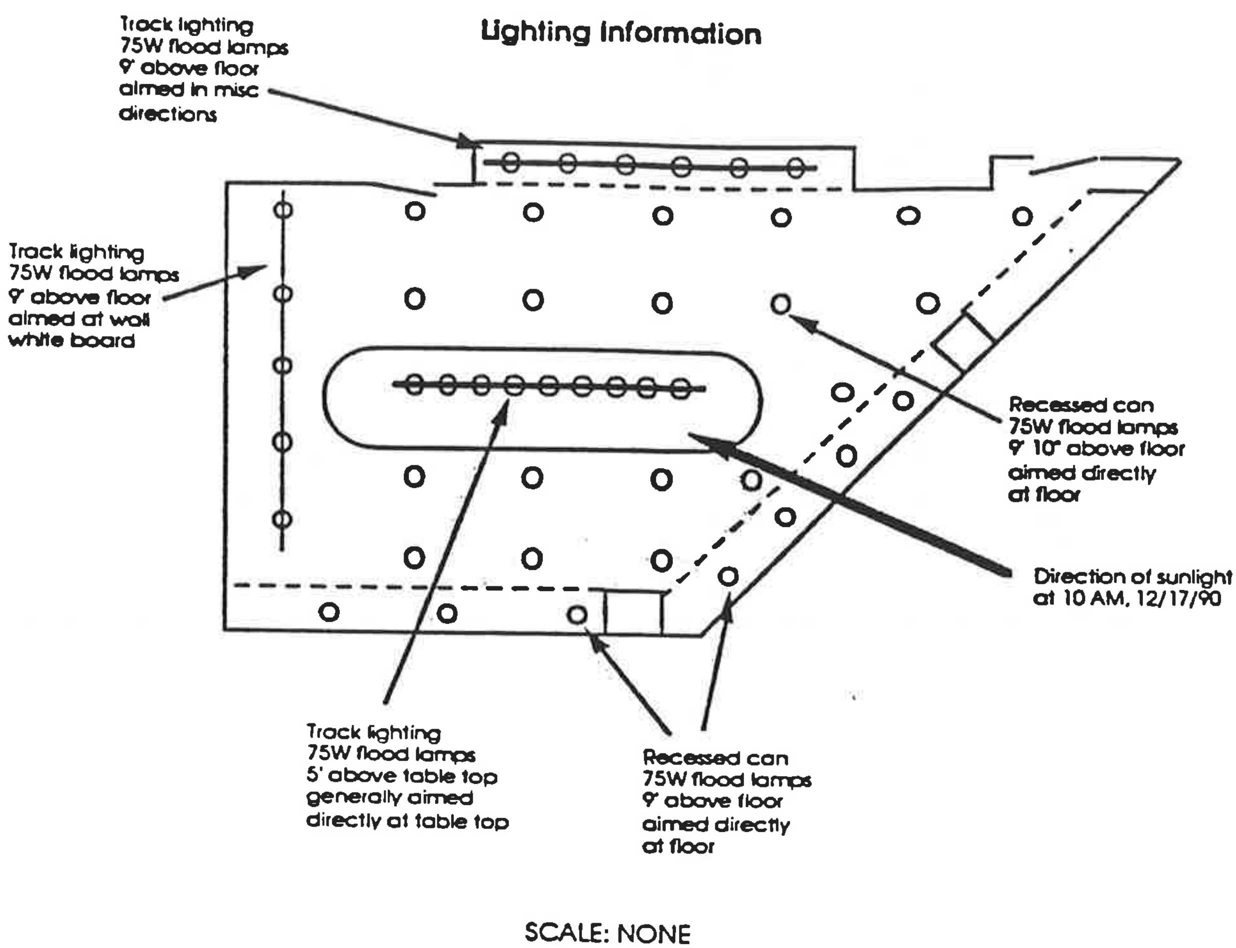
This process was repeated with the receiver located 12 inches from the spot lamp pattern. In this case the error rate began to rise with the transmitter 7 feet from the receiver.

Subsequent testing with the receiver closer to the center of the spot lamp pattern turned out to be impossible because of saturation effects in the receiver front end. Although the signal to noise ratio should have allowed operation with transmitter and receiver located close together, the magnitude of the IR caused the preamps to saturate, and the test was terminated.

Summary:

The test sequence validated most of our assumptions about the performance of the IR transceivers in the presence of interfering IR sources. We were obviously not prepared for the saturation problems that cause the tests to be terminated, but subsequent redesigns have included gain compression circuits that should reduce this effect.

Even without these changes, the tests indicate that IR can be used with restricted range even in the presence of fairly intense, localized IR sources. Users of laptop systems seated at the conference table would be able to communicate with most other users around the table in a collaborative or ad-hoc network. It also appears quite likely that the use of an IR access point or repeater located directly above the table would remove all restrictions to operation of the units in this environment.



Conference Room • Lighting Layout

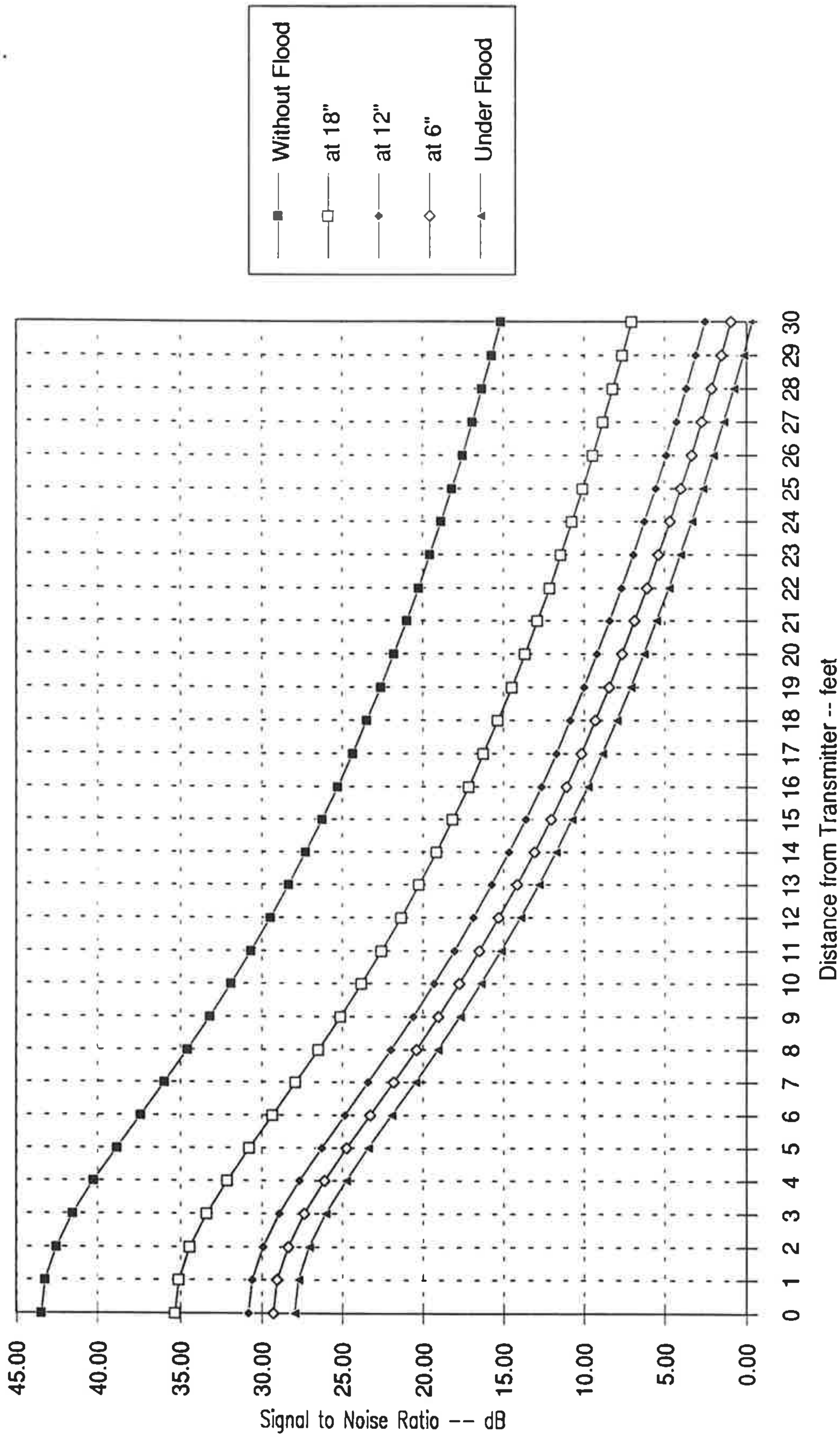
Figure 1

Figure 2

	IR generated current (milliamps)	
Distance from center (inches)	Along the length of the table	Across the table
0	119	119
1	111	110
2	100	98
3	85	87
4	75	76
5	65	66
6	56	58
7	52	49
8	46	42
9	42	37
10	38	32
11	37	27
12	36	24
13	37	21
14	38	19

The background IR level due to sunlight and other sources of illumination in the room averaged 2.5 milliamps ± 1 milliamp.

Figure 3.


Without Flood
at 18"
at 12"
at 6"
Under Flood
Signal to Noise Ratio -- dB
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Distance from Transmitter -- feet
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30