COMMUNICATION SCIENCES AND ENGINEERING

XXI. OPTICAL PROPAGATION AND COMMUNICATION

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The broad objectives of our programs are to determine the fundamental limits on the detection and communication performance that can be realized with important optical channels and to identify, and establish the feasibility of, techniques and devices which can be used to achieve these limits.

1. IMPROVED LOW-VISIBILITY COMMUNICATION

National Science Foundation (Grant ENG78-21603)

U.S. Army Research Office — Durham (Contract DAAG29-90-C-0010)

Robert S. Kennedy, Jeffrey H. Shapiro, Cardinal Warde

This program, part of which is carried out jointly with MIT's Center for Materials Science and Engineering (CMSE), concerns the problem of line-of-sight atmospheric optical communications under low-visibility weather conditions. During the past year substantial progress has been made in our studies of optical propagation in turbid atmospheres,[1-4] communication through optical scattering channels,[5,6] and devices and techniques for space-distributed optical-phase compensation.[6-8] The sections that follow provide an overview of our recent research results in the first two of the preceding areas; the work on phase compensation resides in CMSE.

Our principal objectives for next year are (a) to begin communication-type experiments over our 7.4-km propagation range, and (b) continue to refine and extend our ability to do space-distributed phase compensation. The communication-type experiments will initially employ a frequency-doubled Nd:YAG laser but will evolve towards more realistic systems that might be used in practice. The second aspect of next year's program will entail further experimentation with interference phase loop systems that employ the microchannel spatial light modulator.[8,9] This work will also include a more thorough examination of the limit set by atmospheric coherence time on the utility of phase compensation systems.[6]

a. Propagation Studies

During the past year we have made the transition, in our atmospheric propagation studies, from exploratory propagation measurements to the development and verification of approximate theories to predict the behavior of the low-visibility atmospheric channel. In particular, we have focused our effort on two theories, viz., the multiple-forward scatter (MFS) and the strong multiple-scatter (SMS) approaches. Both theories originate in experimentally observed channel behavior. The MFS approach (first suggested by Mooradian et al.[10]) is an ad hoc small-angle approximation based on a truncated single-scatter phase function. We have developed this model to the point where it can provide[1,5] simple yet realistic predictions for the attenuation, beam spread, angular spread and multipath spread encountered in a line-of-sight low-visibility communication link; a coherence time prediction has also been obtained from this model, but no experimental validation is available as yet. We have also explored the incorporation of a diffusionlike propagation mode into the MFS model so as to have a natural decay of MFS behavior at very large optical thickness.[2]

The second theory we have pursued, the SMS approach, relies for its foundation on the experimentally observed insensitivity of off-axis received power to inhomogeneities in the distribution of scatterers.[3] At present, the SMS model is limited to point sources. It provides, in its present form, an analytical assessment of the transition to diffusion-mode propagation.

For the next year we do not anticipate a major thrust in the propagation area. We will be working on the coherence time question, as it bears on the utility of phase compensation; we may also continue[11] an effort begun earlier[12] to reformulate the multiple-scattering problem in a manner that leads to more explicit results with relatively weak assumptions.

b. Communication Studies

The essential communication-theory features of the low-visibility channel were established some time ago.[13,14] These studies predate the development of realistic propagation models so they are based on ad hoc received-field statistical models. Nevertheless, the early work established two vital principles: that background-light suppression is the key to reliable low-visibility channel optical communication, and that adaptive phase compensation is an important option for achieving this suppression. Lately, we have begun reassessing the communication theory work based on the predictions of the MFS channel model.[5,6] We have found that background-light suppression is indeed vital to maintaining daytime link operability in bad weather, and have considered the merits of the three generic approaches (development of narrow-band wide-angle filters, operation at mid-ultraviolet wavelengths, and the use of adaptive phase compensation) for achieving significant background suppression.

For the next year, our communication studies will be aimed at establishing a demonstration link to explore the experimental viability of some of the receiver structures we have analyzed. Theoretical work on the use of error-correcting codes for the low-visibility channel is also anticipated.

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2. FIBER-COUPLED EXTERNAL-CAVITY SEMICONDUCTOR HIGH-POWER LASER

U.S. Navy — Office of Naval Research (Contract N00014-80-C-0941)

Robert H. Rediker, Robert P. Schloss

This program has as its goal the demonstration of the feasibility of coupling low-power semiconductor lasers in parallel to produce a high-average-power coherent laser beam. Such a laser system would combine the reliability of diode lasers with the higher power and monochromaticity required for several communications applications. In the proposed system, optical fibers from the individual low-power semiconductor lasers are gathered together to act as a source for the external cavity with an appropriate spatial filter to assure that coherence is established over the entire optical bundle emitter.

In the first phase of this program, the coupling of diode laser radiation into, its propagation through, and its outcoupling from fibers are being studied. Experiments are under way to combine a diode laser and a fiber inside an external cavity.

3. ATMOSPHERIC PROPAGATION EFFECTS ON INFRARED RADARS

U.S. Army Research Office — Durham (Contract DAAG29-80-K-0022)

Jeffrey H. Shapiro, David M. Papurt

This program is aimed at obtaining a quantitative understanding of the effects of atmospheric propagation and target reflection characteristics on the performance of compact CO_2 laser heterodyne-reception radars. Under a collaboration arrangement with the Optics Division of the M.I.T. Lincoln Laboratory, the experimental portions of the research are to be carried out on the compact infrared radar under development there.

Since the inception of this program, progress has been made in the following areas:

(i) Initial clear-weather infrared radar measurements have been collected with simultaneous scintillation and seeing data over a 1-km path;

(ii) An analysis of the relative merits of linear and logarithmic frame integration of speckle and scintillation-limited imagery has been carried out;[1]

(iii) A doctoral thesis aimed at extending the models[2] to include the multiple-scattering effects present in bad weather conditions has been initiated.[3]

The research plan for the next year involves: (1) reduction and evaluation of initial clear-weather (turbulence) data; (2) development of computer programs to simulate radar imagery; (3) additional data collection in a variety of turbulence conditions.

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