Long Range Applications

- Deep space probe communications; distances measured in light-years
- Building to building computer data links; very high data rates.
- Ship to ship communications; high data rates with complete security.
- Telemetry transmitters from remote monitors; weather, geophysical.
- Electronic distance measurements; hand held units out to 1000 ft.
- Optical radar; shape, speed, direction and range.
- Remote telephone links; cheaper than microwave

Wide Area Applications

- Campus wide computer networks
- City-wide information broadcasting
- Inter-office data links
- Computer to printer links
- Office or store pagers
- Systems for the hearing impaired; schools, churches, movies
- Cloud bounce broadcasting

Another limitation of light beam communications is that since light can't penetrate trees, hills or buildings. A clear line-of-sight path must exist between the light transmitter and the receiver. This means that you will have to position some installations so their light processing hardware would be in more favorable line-of-sight locations.

A third limitation, one that is often overlooked, is the position of the sun relative to the light transmitter and receiver. Some systems may violate a "forbidden alignment" rule that places the light receiver or transmitter in a position that would allow sunlight to be focused directly onto the light detector or emitter during certain times of the year. Such a condition would certainly damage some components and must be avoided. Many installations try to maintain a north/south alignment to lessen the chance for sun blindness.

How can these light-beam techniques be used?

I believe that optical through-the-air or "Freespace" communications will play a significant role in this century. Many of you are already using some of this new technology without even being aware of it. Most remote control devices for TVs, VCRs and stereo systems rely on pulses of light instead of radio. Many commercially available wireless stereo headphones are using optical techniques to send high quality audio within a room, giving the user freedom of movement. In addition, research is on going to test the feasibility of using optical communications in a variety of other applications. Some military research companies are examining ways to send data from one satellite to another using optical approaches. One such experiment sent data between two satellites that were separated by over 18,000 miles. Space agencies are also exploring optical techniques to improve communications to very distant space probes. Some college campuses and large business complexes are experimenting with optical through-the-air techniques for high-speed computer networks that can form communications links between multiple buildings. Some military bases, banks and government centers are using point-to-point optical communications to provide high speed computer data links that are difficult to tap into or interfere with. But, don't become overwhelmed, there are many simple and practical applications for you experimenters. Several such applications will be covered in this handbook. Below are some examples of existing and possible future uses for light-beam communications.

POSSIBLE USES FOR OPTICAL THROUGH-THE-AIR COMMUNICATIONS

Short Range Applications

- Industrial controls and monitors
- Museum audio; walking tours, talking homes
- Garage door openers
- Lighting controls
- Driveway annunciators
- Intrusion alarms
- Weather monitors; fog, snow, rain using light back-scatter
- Traffic counting and monitoring
- Animal controls and monitors; cattle guards, electronic scarecrow
- Medical monitors; remote EKG, blood pressure, respiration

modulation rate has the capacity to provide virtually all of the typical radio, TV and business communications needs of a large metropolitan area. However, with the addition of more light sources, each at a different wavelength (colors), even more information channels could be added to the communications system without interference. Color channels could be added until they numbered in the thousands. Such an enormous information capacity would be impossible to duplicate with radio.

Why through-the-air communications?

One of the first large scale users for optical communications were the telephone companies. They replaced less efficient copper cables with glass fibers (fiber optics) in some complex long distance systems. A single optical fiber could carry the equivalent information that would require tens of thousands of copper wires. The fibers could also carry the information over much longer distances than the copper cables they replaced. However, complex fiber optic networks that could bring such improvements directly to the small business or home, are still many years away. The phone companies don't want to spend the money to connect each home with optical fibers. Until fiber optic networks become available, through-the-air communications could help bridge the gap. The term “the last mile” is often used to describe the communications bottleneck between the neighborhood telephone switching network and the home or office.

Although light can be efficiently injected into tiny glass fibers (fiber optics) and used like copper cables to route the light information where it might be needed, there are many applications where only the space between the light information transmitter and the receiver is needed. This "freespace" technique requires only a clear line-of-sight path between the transmitter and the distant receiver to form an information link. No cables need to be buried, no complex network of switches and amplifiers are needed and no right-of-way agreements need to be made with landowners. Also, like fiber optic communications, an optical through-the-air technique has a very large information handling capacity. Very high data rates are possible from multiple color light sources. In addition, systems could be designed to provide wide area communications, stretching out to perhaps ten to twenty miles in all directions. Such systems could furnish a city with badly needed information broadcasting systems at a fraction of the cost of microwave or radio systems, and all without any FCC licenses required.

What are some of the limitations of through-the-air communications?

The main factor that can influence the ability of an optical communications system to send information through the air is weather. "Pea soup" fog, heavy rain and snow can be severe enough to block the light path and interrupt communications. Fortunately, our eyes are poor judges of how far a signal can go. Some infrared wavelengths, used by many of the light transmitters in this book, are able to penetrate poor weather much better than visible light. Also, if the distances are not too great (less than 5 miles), systems can be designed with sufficient power to punch through most weather conditions. Unfortunately, little useful information exists on the true effects weather has on long-range optical systems. But, this should not be a hindrance to the development of a through-the-air system, because there are many areas of the world where bad weather seldom occurs. In addition, it would be a shame to completely reject an optical communications system as a viable alternate to radio solely due to a few short interruptions each year. Even with present day systems, TV, radio and cable systems are frequently interrupted by electrical storms. How may times has your cable or TV service been interrupted due to bad weather? I think the advantages that through-the-air communications can provide outweigh the disadvantages from weather.

INTRODUCTION

Brief History

Communications using light is not a new science. Old Roman records indicate that polished metal plates were sometimes used as mirrors to reflect sunlight for long range signaling. The U.S. military used similar sunlight powered devices to send telegraph information from mountain top to mountain top in the early 1800s. For centuries the navies of the world have been using and still use blinking lights to send messages from one ship to another. Back in 1880, Alexander Graham Bell experimented with his "Photophone" that used sunlight reflected off a vibrating mirror and a selenium photo cell to send telephone like signals over a range of 600 feet. During both world wars some lightwave communications experiments were conducted, but radio and radar had more success and took the spotlight. It wasn't until the invention of the laser, some new semiconductor devices and optical fibers in the 1960s that optical communications finally began getting some real attention.

During the last thirty years great strides have been made in electro-optics. Lightbeam communications devices are now finding their way into many common appliances, telephone equipment and computer systems. On-going defense research programs may lead to some major breakthroughs in long range optical communications. Ground-station to orbiting satellite optical links have already been demonstrated, as well as very long range satellite to satellite communications. Today, with the recent drop in price of some critical components, practical through-the-air communications systems are now within the grasp of the average experimenter. You can now construct a system to transmit and receive audio, television or even high speed computer data over long distances using rather inexpensive components.

Why Optical Communications?

Since the invention of radio more and more of the electro-magnetic frequency spectrum has been gobbled up for business, the military, entertainment broadcasting and telephone communications. Like some of our cities and highways, the airwaves are becoming severely overcrowded. Businesses looking for ways to improve their communications systems and hobbyist wishing to experiment are frustrated by all the restrictions and regulations governing the transmission of information by radio. There is simply little room left in the radio frequency spectrum to add more information transmitting channels. For this reason, many companies and individuals are looking toward light as a way to provide the needed room for communications expansion. By using modulated light as a carrier instead of radio, an almost limitless, and so far unregulated, spectrum becomes available.

Let me give you an example of how much information an optical system could transmit. Imagine a single laser light source. Let's say it is a semiconductor laser that emits a narrow wavelength (color) of light. Such devices have already been developed that can be modulated at a rate in excess of 60 gigahertz (60,000MHz). If modulated at a modest 10GHz rate, such a single laser source could transmit in one second: 900 high density floppy disks, 650,000 pages of text, 1000 novels, two 30-volume encyclopedias, 200 minutes of high quality music or 10,000 TV pictures. In less than 12 hours, a single light source could transmit the entire contents of the library of congress. Such a

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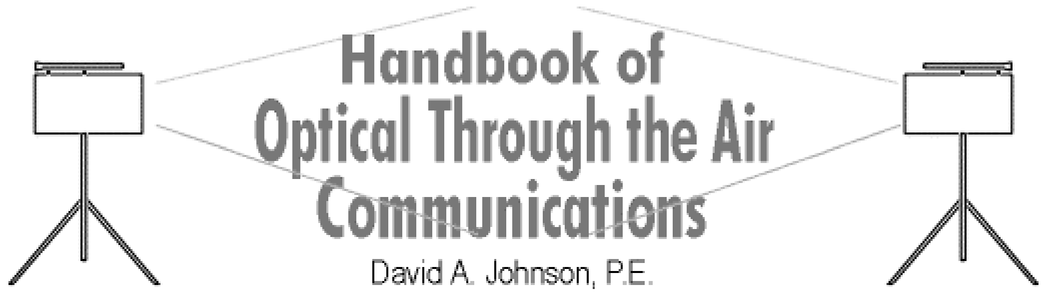
communications. It seemed logical to me that many of the techniques being used in fiber optic communications could also be applied in through-the-air communications. I was puzzled by the technical hole that seemed to exist. This lack of information started my personal crusade to learn more about communicating through-the-air using light.

During my studies I reviewed many of the light communications construction projects that were published in some electronics magazines. I was often disappointed with the lack of sophistication they offered and usually found their performance lacking in many ways. Many of the circuits were only able to transmit a signal a few feet. I thought that with a few changes they could go miles. I was determined to see how far the technology could be pushed without becoming impractical. So, I took many of the published circuits and made them work better. I discovered better ways to process the weak light signals and methods to get more light from some common light emitters. I found ways to reduce the influence ambient light had on the sensitive light detector circuits and I developed techniques to increase the practical distance between a light transmitter and receiver. I also experimented with many common light sources such as fluorescent lamps and xenon camera flash tubes to see if they too could be used to send information. To my delight they were indeed found to be very useful.

Today, my crusade continues. I am still discovering ways to apply what I have learned and I'm still making improvements. However, after having devoted some 20 years of work toward advancing the technology I felt it was time to collect what I have learned and pass some of the information on to others. Thus, this book was conceived.

This handbook may be found at http://www.imagineeringezine.com/air-bk2.html.



PREFACE

About the author:

David A. Johnson, **P.E**. is consulting electronics engineer with a broad spectrum of experience that includes product research, design and development; electronic circuit design; design, building and testing prototypes; electro-optics; and custom test instruments. Doing business for more than 17 years as David Johnson and Associates, Dave has established himself as an electronics engineer who can provide a variety of services.

His proficiency is based on "hands-on" experience in general engineering, electronics and electro-optics. Mr. Johnson is licensed by the State of Colorado as a Professional Engineer; he is a graduate of University of Idaho and is a member of IEEE. Holds three patents and has four more pending.

He remains well informed of the latest scientific and engineering advancements through independent studies. Dave is a published author with articles and designs in *EDN*, *Electric Design*, *Midnight Engineering* and *Popular Electronics*.

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I became interested in optical through-the-air communications around 1980. At that time I was doing research in high-speed fiber optic computer data networks for a large aerospace company. My research assignment was to produce a report that made recommendations for the best ways of using the latest optical fiber technologies to satisfy the increased demands for fast data transmission in the aerospace industry. My research involved pouring through mountains of technical papers, scientific journals, patents and manufacturer's application notes.

As my research progressed I began to notice that nearly all the optical communications systems described used optical fibers. Little was being written on the subject of through-the-atmosphere