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Optical Communication

In The New Frontier, I report on activities in the "world above 1 GHz." Usually, this is taken to mean the region of the electromagnetic spectrum between 1 GHz and 300 GHz, but there is another region of interest: the visible and near-infrared part of the spectrum. Those who know ARRL VHF contest rules well are no doubt aware of the rule which reads: "Above 300 GHz, contacts are permitted for contest credit only between licensed amateurs using coherent radiation on transmission (eg, laser) and at least one stage of electronic detection on receive." There hasn't been much optical communications work reported recently. The farthest amateur laser DX contact that I know of is a 15-mile contact between the Ventura County ARC, K6MEP, and Steve Noll, WA6EJO, way back in 1979. To encourage activity in the above-300-GHz region, ARRL has introduced a VUCC award for laser contacts. See League Lines in August *QST* for details.

In this month's column, I'll outline some basic principles of optical communications that may be of use to those who are interested in trying it. I'll limit this discussion to free-space communications, rather than optical-waveguide (fiber optics) systems, and I won't discuss high-data-rate systems or heterodyne-detection schemes.

Transmitters

In ARRL contests, *coherent radiation* must be used. For practical amateur purposes, this dictates the use of lasers. Two kinds of lasers are fairly commonly available on the surplus market: One is the Helium-Neon (HeNe) gas laser, which operates on a wavelength of 0.6328 microns (0.6328×10^{-6} meter—red light—corresponding to a frequency of 474 THz or 474,000 GHz). The second type is the semiconductor-diode laser, usually operating in the near-infrared region (wavelengths between 1 and 2 microns). HeNe lasers are used in commercial equipment such as supermarket checkout scanners and some photocopiers. Semiconductor lasers in the near IR region are used as transmitters in fiber-optic systems, usually at 1.3 and 1.5 microns. HeNe lasers are easier to work with than semiconductor-diode types because they have visible beams. They also usually have less-divergent beams than semiconductor lasers, which is an advantage.

HeNe lasers in the 1-mW output class sell for between $50 and $200 at flea markets and through surplus catalogs. Beam divergence is an important parameter (it corresponds to antenna gain in a lower-frequency system) and is usually expressed in radians (1 radian = 57.3°). Beam divergence is a result of diffraction, and is given by the relationship:

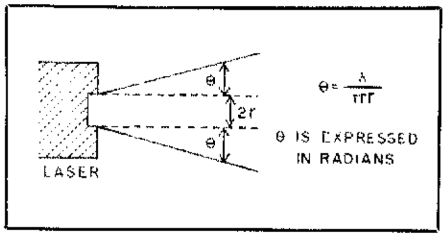

Fig 1—Illustration of diffraction-limited beam divergence of a laser beam, as discussed in the text.

$$\theta = \frac{\lambda}{\pi \times r} \qquad \text{(Eq 1)}$$

where

θ = the half angle of beam divergence, as shown in Fig 1, and

r = beam radius.

The larger the beam diameter, the lower the beam divergence. An analogy, in microwave antenna terms, is that large parabolic dish antennas have narrower beamwidths than smaller antennas. The relationship in Eq 1 applies to all antennas, and predicts, for example, that the beamwidth of a 1-meter dish at 10 GHz is 2.2°. For a HeNe laser with a beam diameter of 0.8 mm, the "beamwidth" (divergence) turns out to be 1.008×10^{-3} radians, or 0.058°. For a 10-GHz antenna to have the same beamwidth, it would have to be 125 feet in diameter!

One aspect of optical communication now becomes clear: very high transmitter "antenna gain" (low beam divergence) is inherent in HeNe laser sources. The same applies, to a lesser extent, to diode laser sources, which usually show somewhat higher beam divergence (larger beamwidth) and hence lower gain. The beam can be sharpened even more by expanding it, thereby reducing diffraction-limited beam spreading. The optical layout of a beam expander is shown in Fig 2. If a beam is expanded 10 times, then the beam divergence is reduced by a factor of 10, and the area illuminated by the beam at any distance is reduced by a factor of 100. This results in 100 times the power density at any given distance, or an effective system gain of 20 dB.

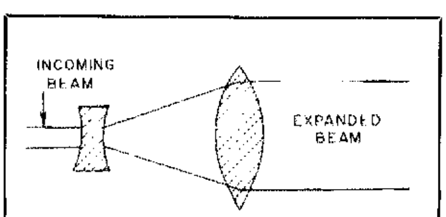

Fig 2—Optical expansion of a laser beam.

Lasers can be modulated by several methods. Some lasers can be modulated via their power supplies. For other lasers, the use of external modulators is required. An electro-optic modulator (a device in which optical transmittance can be altered by the application of an electric field) is ideal for this function. Such devices are used commercially, but are not often found on the surplus market, and are expensive to buy new. The simplest modulation method, ideal for normal amateur CW speeds, is simply to block off the beam mechanically with a solenoid arrangement. This works fine and gives 100% modulation, but has limited high-speed potential.

Receivers

The simplest optical-communications receiver is the human eye! *Warning: lasers are dangerous at close range.* Permanent eye damage can result from looking into the output beam of even a low-power laser! *Don't try it.* As mentioned earlier, ARRL contest rules require "...at least one stage of electronic detection on receive." Direct detection (analagous to a sort of "crystal set") is probably the only practical scheme that amateurs can use. Fortunately, this is not difficult to do. Silicon photodiodes have good response to the red part of the visible spectrum. Their sensitivity is often quoted in terms of amperes per watt (current output for a given level of incident optical power). A value of 300 mA/W is typical for a good silicon photodiode. Photodiode sensitivity is limited by internally generated noise and dark current (which varies from 10^{-7} to 10^{-10} A, depending on diode characteristics).

Photomultiplier tubes may also be used as detectors. They have much higher gains than photodiodes, but require high-voltage supplies for operation. As at lower radio frequencies, a narrow-bandwidth receiver will give better sensitivity than a wideband receiver. Because lasers are generally monochromatic (single-frequency) sources, a narrowband optical filter can be used ahead of the receiver. Such a filter with a passband of 0.6328 ± 0.005 microns and a 3-dB insertion loss can be bought for $20 to $30.

The receiving "antenna" is usually a telescope. The larger the lens or mirror, the higher the gain. Because the purpose of the telescope is to concentrate incoming light onto the photodiode (which typically has an area of several square millimeters), diffraction-limited optics are not necessary. Almost any telescope will perform this function quite well, regardless of minor optical imperfections. Converting detector output into a readable signal is left to you, but basically consists of a few stages of amplification, noise filtering, a comparator and a tone oscillator.

A Sample Path

To estimate signal levels over a given optical link, let's consider the following example: A 1-mW HeNe laser with a 0.6-mm beam diameter and a 1.3×10^{-3}-radian beam divergence is being used to communicate over a 1-mile path. The receiving optics used are 8 inches in diameter.

Using simple geometry, it can be calculated that the laser beam will expand from its initial diameter of 0.6 mm to about 6.8 feet over the 1-mile path. The beam will thus be spread over an area of 37 square feet. The 8-inch-diameter mirror has an area of 0.35 square feet, and it will therefore intercept 0.95% of the laser radiation, or about 9.5 μW. A properly aligned 10 × beam expander at the transmitter would increase this amount to 0.95 mW. The sensitivity, noise and dark current of the detector, in combination with the amount of unwanted (background) light received, determines whether or not this is a detectable signal (in most cases, it should be). Of course, it is very advantageous to use the narrowband optical filter to reduce background light, and/or preferably work at night! The most difficult part of setting up an optical link such as this is in lining up the laser and receiving telescope optics.

Summary

I hope that this gives you some idea of what is involved in free-space optical communications. Optical systems of this type are under serious consideration as the communications links between Earth and the next generation of deep-space probes. It should be possible to communicate with spacecraft at distances of up to 9.3×10^{10} miles (1000 astronomical units) at 20 kbit/s using a 10-W laser. I am interested in hearing from any readers who are experimenting with optical communications systems.

One source for new lasers, filters and other optical components is Edmund Scientific, 101 E Gloucester Pike, Barrington, NJ 08007. At the time of writing (July), Timeline was selling a 10-mW HeNe laser with a 140-MHz acousto-optic modulator for about $500. Timeline can be reached at 1490 W Artesia Blvd, Gardena, CA 90247, tel 213-217-8912. *Sky and Telescope* magazine is a good source of telescopes and telescope optics suppliers.

A Dipper Amplifier for Impedance Bridges

(continued from page 25)

impedance dial and the dipper level control for maximum or full scale on the bridge meter. Proceed with normal bridge operation.

If you want the amplifier to cover the 1.8-MHz band, more turns are needed on broadband transformer T1. I suggest using 25 turns on the primary and 9 turns on the secondary. The high-frequency limit may be reduced, but should not go below 30 MHz.

Notes

[1]M. Wilson, ed., *The 1988 ARRL Handbook* (Newington: ARRL, 1987), p 25-33.
[2]D. DeMaw, "Homemade Circuit Boards—Don't Fear Them," *QST*, Aug 1987, p 14.

Radio and electronics have been Andrew Griffith's hobby since he was 15. He was first licensed in 1951, received his Advanced class license in 1952 and graduated to Extra Class in 1983. In 1943, Andrew earned a BS degree in Chemical Engineering from Virginia Polytechnic Institute. After a tour of duty with the Army in Europe, he received his MS degree in 1947. His industrial career was spent with the Dupont Company.

Now retired, Andrew devotes his free time to ham radio, golf and staying out of his wife's hair! His primary radio interests are its technical and building aspects. Andrew's homemade equipment includes a linear amplifier and a digital readout for his Kenwood TS-520 transceiver. He occasionally chases DX and is active in the Volunteer Examiner program.

Exam Info

CHANGING CALL SIGNS

Most licensees who upgrade are eligible to request call sign changes; many other licensees who do not seek an upgrade are also eligible. (Technician class amateurs who already hold a call sign beginning with "N," followed by a numeral and three suffix letters and who upgrade to General are not eligible for a change as the call signs for both classes are issued from the same call sign block.)

If you're eligible (and interested), all that is needed to request a call sign change is to file a Form 610 with the FCC. Check off Item 2E ("Change Call Sign"), fill out the remainder of Section 1 (don't forget to sign it!), and mail it with a photocopy of your current *signed* license to the FCC's address at the top of the 610. Your new license should show up in just a few weeks.

One warning, though: Once you have been issued a new call sign, your former call will not be reissued to you. Be sure that you really want to change it before your 610 goes in the mail!

Note: The FCC is currently considering adopting a proposal, PRB-3, that may allow amateurs to select call signs from certain as-yet-undetermined call sign blocks. Watch *QST* for details.—*Jim Clary, WB9IHH, Manager, ARRL/VEC*

Strays

CODE SPEED RECORD TO BE CHALLENGED AT PORTLAND CONVENTION

☐ One of the features of this year's ARRL National Convention is an effort to establish a new speed record in the international Morse code.

The eliminations will begin on Friday afternoon, Sep 9 with an official speed run at 50 WPM. Participants are encouraged to bring their favorite typewriters. Transcribing devices must be capable of same-time output. Editable data storage features may not be used.

Transmissions will be approximately five minutes of plain text, of which one minute must be copied accurately (including word spaces in their proper locations) for credit to be granted. For those traveling a great distance, a typewriter could possibly be supplied. For more information or pre-registration please contact: H. Lea T. Ball, AL7W, 4536 SE Gladstone St, Portland OR 97206, tel 503-777-1032.

QST congratulates...

☐ Bill Lowell, K7JBQ, of Grosse Pointe, Michigan who won first place in the 1988 American Auto Racing Writers and Broadcasters Assn writing contest in the magazine writing category.