AC 61-27C

INSTRUMENT FLYING HANDBOOK

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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DEPARTMENT OF TRANSPORTATION

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FOREWORD

General Aviation in the United States has grown tremendously in recent years. The aircraft industry has designed aircraft to satisfy the requirements of business firms, professional people, crop dusters, flight-training schools, and others. Our aviation community is thus expanding to include an ever-broadening spectrum of the American public.

The Federal Aviation Administration is vitally concerned that this huge air travel potential be exploited in a safe and orderly manner. To this end, development of sound training programs and materials receive high priority among the many activities of the FAA. Since a wide variety of general aviation aircraft possess instrument flight capability—a key factor in achieving greater aircraft utilization—more and more pilots are therefore preparing themselves to "fly the weather."

The *Instrument Flying Handbook* has been developed in response to this increased flight activity and to the continuing requests from individuals and training organizations for an FAA handbook which is oriented to civilian instrument flying. Together with other flight training materials, the handbook emphasizes the concept that an informed pilot is a safe pilot. In this respect, the handbook supports the primary objective of the Federal Aviation Administration—safety in flight.

This handbook, along with the *Airman's Information Manual*, *Aviation Weather, AC 00-6A*, and *Aviation Weather Services, AC 00–45B* (or other equivalent handbooks on meteorology), will provide the flight student with the basic information needed to acquire an FAA instrument rating. Like any basic text, this one should be supplemented by technical periodicals, textbooks, and training aids, depending upon individual training needs, interests, and objectives. The book is designed for the reader who holds at least a private pilot's certificate and who is knowledgeable in all of the areas discussed in the *Pilot's Handbook of Aeronautical Knowledge (AC 61–23B)*.

In this edition, the repetition of material already published in the *Airman's Information Manual* is held to a minimum. Instead, AIM references are cited throughout the text wherever they are applicable.

The reader must be aware that regulations, air traffic control procedures, charts, and certain other materials referred to in this handbook are subject to change and amendment. Any question regarding currency of these items should be resolved by checking pertinent source materials or the appropriate FAA office.

The *Instrument Flying Handbook*, issued as Advisory Circular 61–27C, was prepared by the Flight Standards Service of the Federal Aviation Administration and supersedes AC 61–27B. Many valuable contributions were provided by other organizations in FAA. Acknowledgement is made to the numerous firms whose equipment or products are illustrated in this publication. The inclusion of such illustrations *does not*, however, constitute an endorsement by the FAA.

Comments regarding this publication should be directed to the U.S. Department of Transportation, Federal Aviation Administration, Flight Standards National Field Office, P.O. Box 25082, Oklahoma City, Okla. 73125.

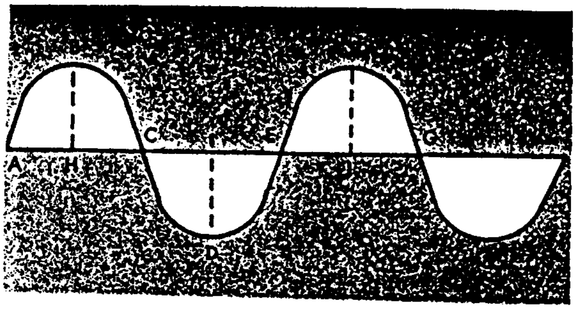


FIGURE 7-1. Wave transmission.

of a wave is the number of cycles completed in one unit of time. If 10 cycles are completed in one second, the wave frequency is 10 cycles per second. Since radio wave cycles per unit of time involve very high numbers, radio frequencies are expressed in kilo Hertz* (thousands of cycles per second) or Mega Hertz (millions of cycles per second). Thus, a frequency of 1,000 Hz equals 1 kHz, and 1,000 kHz equals 1 MHz.

*The Federal Aviation Administration, in conformance with worldwide practice, has formally adopted the term "Hertz" as the basic unit of frequency, meaning cycle or cycles per second. The standard abbreviations Hz (Hertz); kHz (kilo Hertz); and MHz (Mega Hertz) are therefore used in this publication.

Current is the flow of electrons through a conductor. Direct current (DC) flows only in one direction. Alternating current (AC) flows in one direction during a given time interval, then in the opposite direction for the same interval, reversing continuously. An alternating current can be represented as a continuous change of direction of flow of electrons from positive to negative (Fig. 7-2).

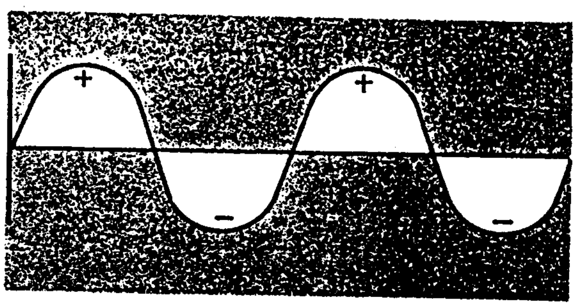


FIGURE 7-2. Alternating current.

Radio Waves.—When an electric current flows through a wire, a magnetic field is generated around the wire. When alternating current flows through a wire, the magnetic field alternately builds up and collapses. Radio waves are produced by sending a high-frequency alternating current through a conductor (antenna). The frequency of the wave radiated by the antenna is equal to the frequency, or number of cycles per second, of the alternating current. The velocity of the radiated wave is 186,000 miles per second.

Frequency Bands.—Radio frequencies extend from approximately 20 kilo Hertz to over 30,000 Mega Hertz. Since different groups of frequencies within this range produce different effects in transmission, radio frequencies are classified into groups or frequency bands, according to these differences.

Band	*Frequency Range*
Low-frequency (L/F)	30 to 300 kHz
Medium-frequency (M/F)	300 to 3000 kHz
High-frequency (H/F)	3000 kHz to 30 MHz
Very high frequency (VHF)	30 to 300 MHz
Ultra high frequency (UHF)	300 to 3000 MHz

Characteristics of Radio Wave Propagation.—All matter has a varying degree of conductivity or resistance to radio waves. The Earth itself acts as the greatest resistor to radio waves. Radiated energy that travels near the ground induces a voltage in the ground that subtracts energy from the wave, decreasing the strength (attenuating) of the wave as the distance from the antenna becomes greater. Trees, buildings, and mineral deposits affect attenuation to varying degrees. Radiated energy in the upper atmosphere is likewise affected as the energy of radiation is absorbed by molecules of air, water, and dust. The characteristics of radio wave propagation varying according to the frequency of the radiated signal, determining the design, use, and limitations of both ground and airborne equipment.

Low-Frequency Radio Wave Propagation.—A radio wave radiates from an antenna in all directions. Part of the energy travels along the ground (ground wave) until its energy is dissipated. The remainder of the transmitted energy travels upward into space (sky wave) and would be lost if it were not reflected in the ionosphere by highly charged particles (ions) caused by the Sun's radiation. Reflection of radio signals back to the Earth permits reception of the signals at varying distances from the transmitter. The distance is determined by the height and density of the ionosphere and the angle at which the radiated wave strikes the ionosphere. The height and density of the ionosphere varies with the time of day, seasons, and latitude since its composition is determined by solar radiation. See Figure 7-3.

The distance between the transmitting antenna and the point where the sky wave first returns to the ground is called the *skip distance* (Fig. 7-3). The distance between the point where the ground wave can no longer be received and the sky wave returned is called the *skip zone.* Since solar radiation varies the position and density of the ionosphere, great changes in skip distance occur at dawn and dusk when fading of signals is more prevalent.

High-Frequency Wave Propagation (3,000 kHz to 30 MHz).—The attenuation of the ground wave at frequencies above approximately 3,000 kHz is so great that the ground wave is of little use except at very short distances. The sky wave must be utilized, and since it reflects back and forth from sky to ground, it may be used over long distances (12,000 miles, for example).

Very High Frequency Propagation (30 to 300 MHz).—At frequencies above about 30 MHz, there

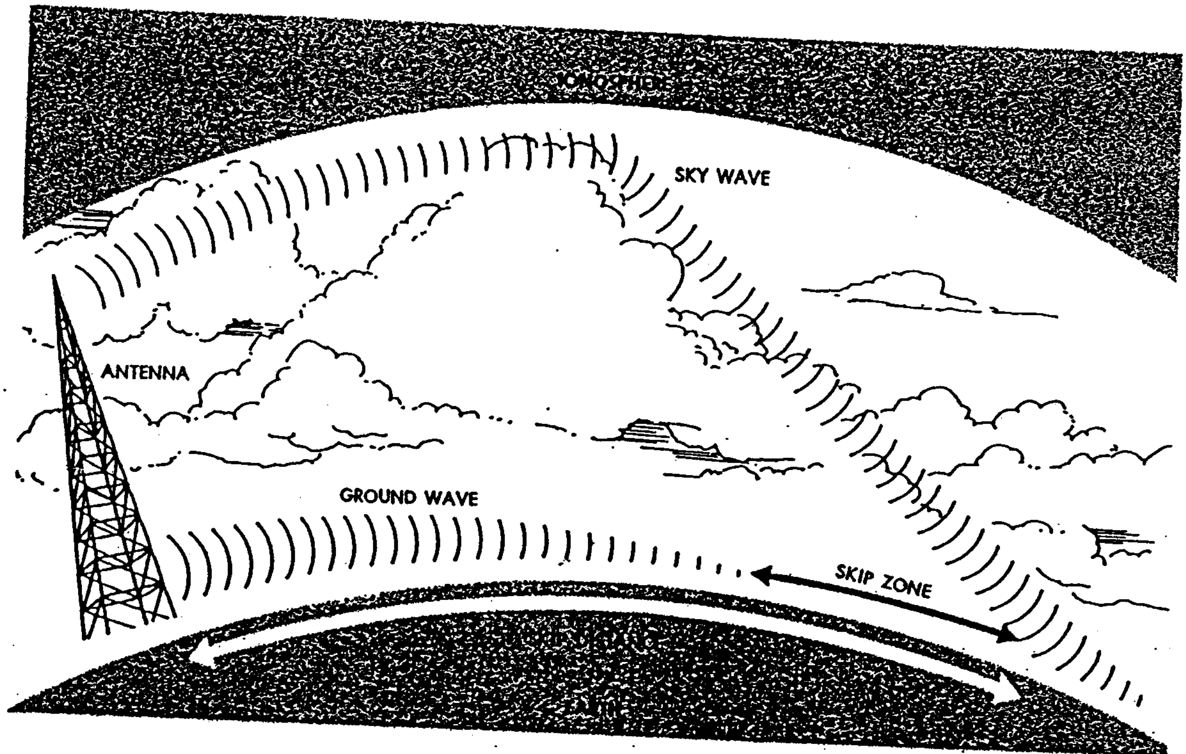


FIGURE 7–3. Low-frequency radio wave propagation.

is practically no ground wave propagation and ordinarily no reflection from the ionosphere. Thus, use of VHF signals is possible only if the transmitting and receiving antennas are raised sufficiently above the surface of the Earth to allow the use of a direct wave. This type of radiation is known as "line-of-sight" transmission. Accordingly, the use of VHF/UHF radio waves is limited by the position of the receiver in relation to the transmitter (Fig. 7–4).

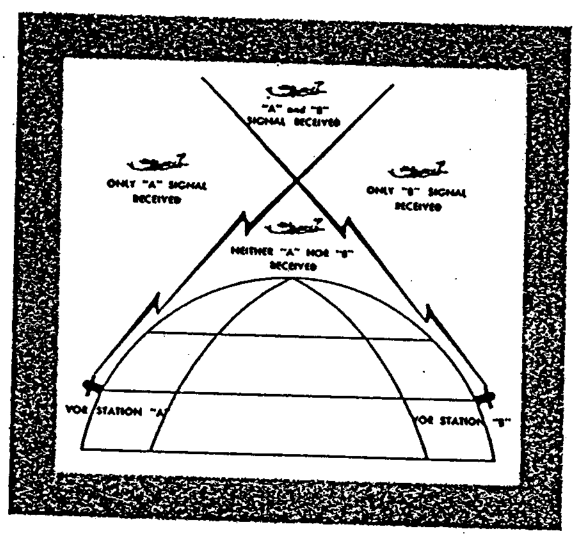


FIGURE 7–4. Line-of-sight transmission.

When using airborne VHF/UHF equipment, it is of the utmost importance that this limitation be understood. The range of VHF/UHF transmission increases with altitude, and may be approximately determined by the following simple method: Multiply the square root of the aircraft altitude in feet by 1.23 to find the VHF/UHF transmission range in nautical miles. For example, an aircraft flying 3,600 feet above flat terrain will receive VHF/UHF signals approximately 74 nautical miles from the transmitter.

Static Disturbance to Reception of Radio Waves

Static, whether it originates away from the aircraft in lightning discharges or from electrostatic discharges from the aircraft surfaces, distorts the radio wave and interferes with normal reception of both communications and navigation signals. Low-frequency airborne equipment is particularly subject to static disturbance. Signals in the higher frequency bands are static-free.

Precipitation static occurs when static electricity is generated on various aircraft surfaces in flight and is discharged onto other surfaces or into the air. An aircraft generally accumulates little or no static charge when flying in clear atmosphere. But an aircraft flying in particle-laden air may encounter precipitation static because of charged particles that (1) adhere to the aircraft, (2) create a charge through frictional contact, or (3) divide into

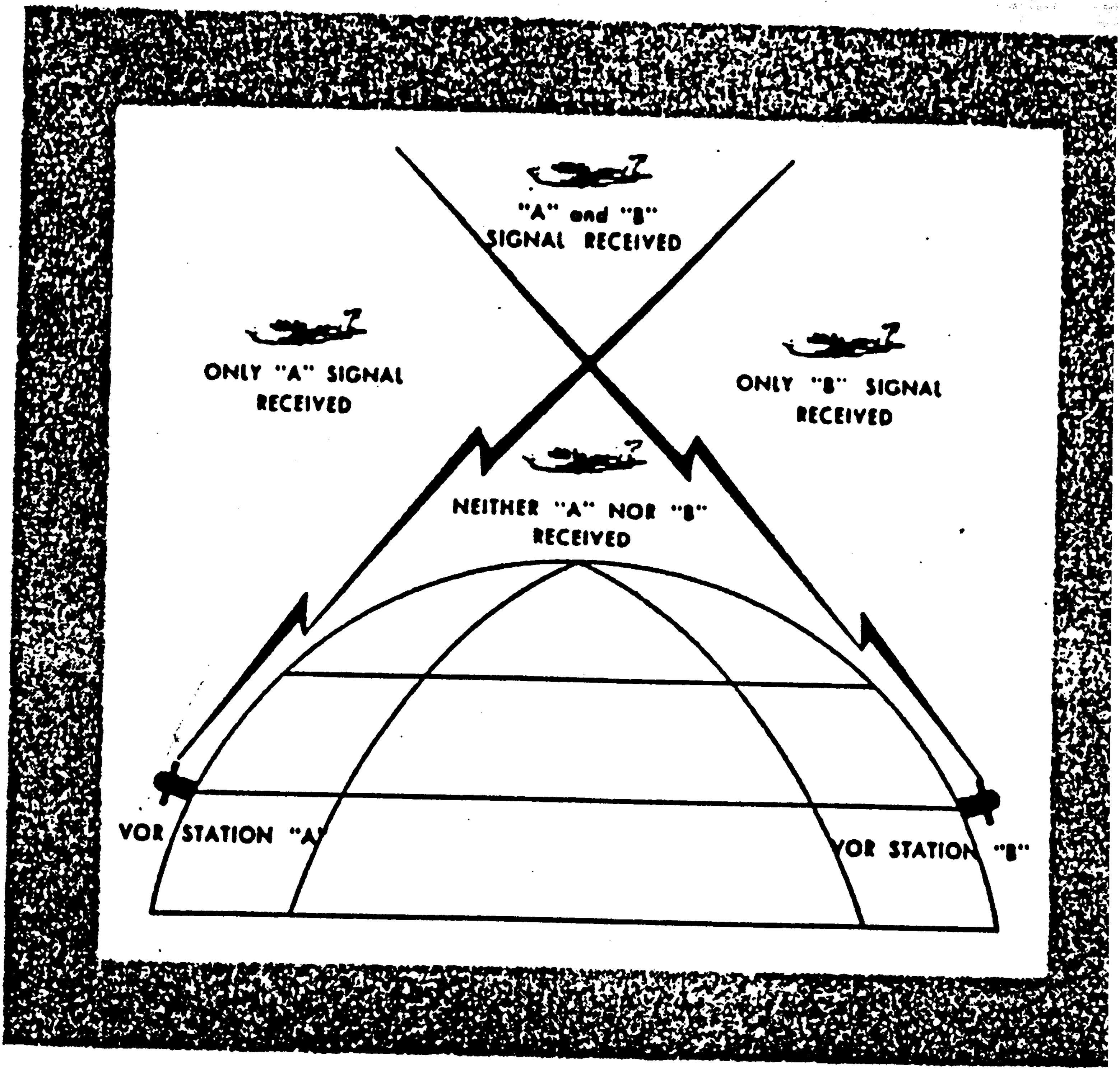
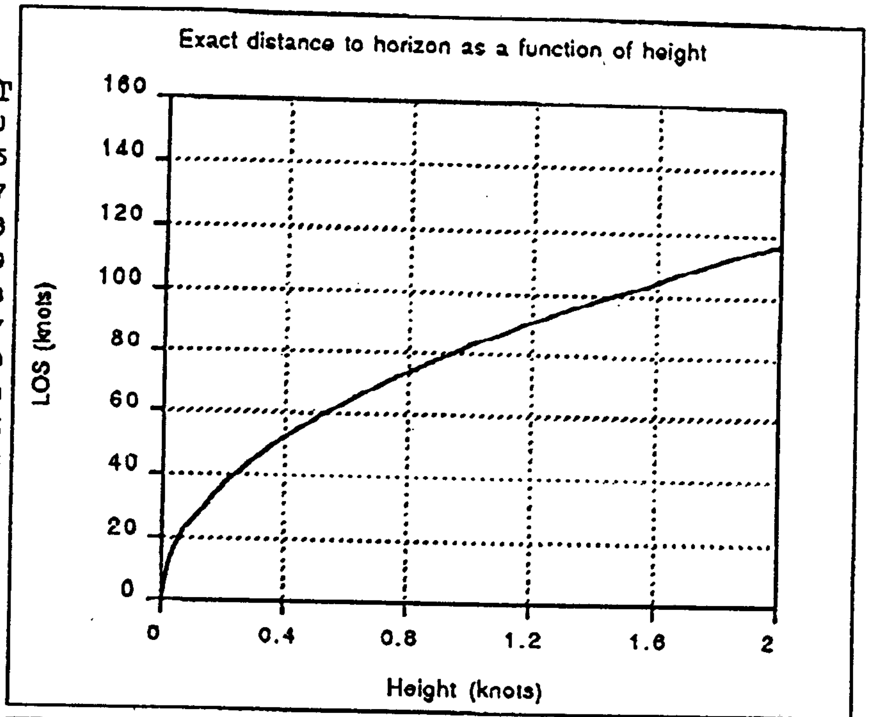
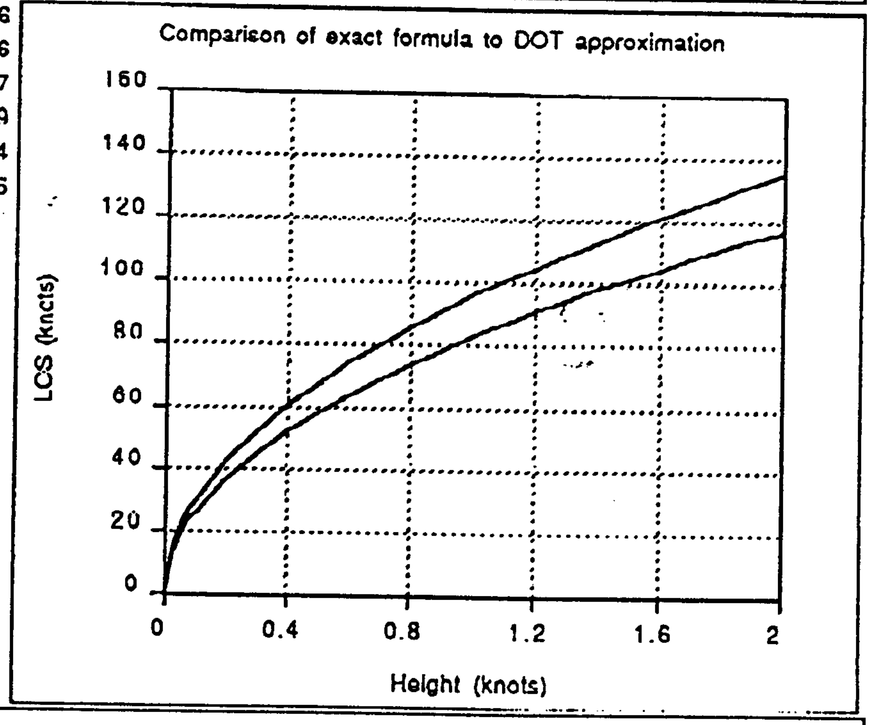


FIGURE 7–4. Line-of-sight transmission.

Earth radius 3437.75 knots

h	LOS	LOS (DOT
0	0	0
0.025	13.1105	15.1545
0.05	18.541	21.4317
0.075	22.708	26.2483
0.1	26.2208	30.309
0.2	37.0814	42.8633
0.3	45.4147	52.4967
0.4	52.4398	60.6179
0.5	58.6287	67.7729
0.6	64.2238	74.2415
0.7	69.3688	80.19
0.8	74.1575	85.7287
0.9	78.6549	90.9269
1	82.9085	95.8453
1.1	86.9542	100.523
1.2	90.8198	104.993
1.3	94.5269	109.28
1.4	98.094	113.406
1.5	101.536	117.386
1.6	104.864	121.236
1.7	108.09	124.967
1.8	111.223	128.59
1.9	114.269	132.114
2	117.236	135.546





D = r * arccos(r / (r + h)); D, h, r in knots

DOT approximation: D = 1.23 * sqrt(h); h in feet; D in knots