NATURE'S INVISIBLE RADIO MIRROR

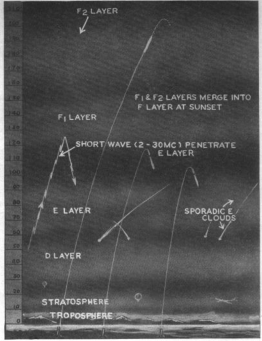

Fig. 1—The Earth's atmosphere.

Between 40 and 600 miles above the earth is an atmospheric layer—the ionosphere—that makes much of the world's long-distance radio communications possible

By JAMES F. VAN DETTA, WA2FQZ

A TEEN-AGER slumps into an easy chair and contentedly sips his soft drink as he loudly taps his feet in time with a strident rock 'n' roll tune from a broadcast receiver. An amateur radio operator sits before his home-made transmitter and talks with a fellow ham on the other side of the earth. A young child sits very close to the television set and gleefully claps his small hands as mild-mannered Huckleberry Hound jogs nonchalantly across the screen. At a desolate and unpublicized outpost, an alert missile-tracking specialist listens intently to a signal from space as he carefully tracks an American rocket shot.

All these are instances of electromagnetic radiation or "radio waves," but only one, the amateur's contact with the other side of the earth, involves nature's invisible radio mirror—the ionosphere.

A certain dictionary coyly defines the ionosphere as the ionized layers that constitute the outer regions of the earth's atmosphere. Such a definition is correct, but not very informative. Let's look further.

Fig. 1 is a simple representation not drawn to scale, but you can easily see that the lowest layer of the atmosphere is the troposphere. It extends about 6 miles above the earth and is known as the "weather layer" because it's within this comparatively narrow region that the earth's weather exists.

The stratosphere is directly above the troposphere. It extends to a height of about 40 miles. This is a region in which the air temperature remains practically constant and doesn't decrease with height as it does in the troposphere where the average temperature decreases about 3.5° each 1,000 feet.

The ionosphere begins above the stratosphere and goes up to at least 600 miles. Until recently, it was believed that the ionosphere extended to about 250 miles; but earth satellites have given us information to indicate that 250 miles is a much too conservative figure.

"So what causes the ionization in the ionosphere?" you may ask impatiently. The answer is "The sun's rays." For example, an ultraviolet ray from the sun (the kind that causes your skin to tan and sunburn) strikes a particle of air high up in the outer atmosphere and knocks an electron from it. Since an ion is an electrically charged particle that has fewer or more electrons than normal, the obvious result of such a collision is a positive ion (a particle minus an electron) and, of course, a free electron. Countless such collisions produce innumerable ions and free electrons, and thus an "electrified," or ionized, layer is produced.

Ionosphere layers

The D-layer is directly above the stratosphere. It may be anywhere between 30 and 55 miles wide—the height, depth and degree of ionization on any ionosphere layer depend upon the time of day, the season of the year and the amount of sunspot activity.

The D-layer forms in a fairly dense region of the atmosphere, so the particles that are ionized there recombine rapidly. Since the amount of ionization is directly related to the amount of sunlight, ionization in the D-layer is greatest around noon and disappears completely after sundown.

The D-layer is not useful for communications. The dense ionization in this layer absorbs a great deal of the energy of certain radio waves—say those below 10 mc. The degree of absorption is inversely proportional to the frequency. Therefore, on waves above 10 mc, for example, absorption is relatively small. Many short-wave listeners and radio amateurs curse the D-layer as the culprit when the 80-meter amateur band (3.5–4.0 mc) "goes dead" for a while around noontime.

The E-layer is the lowest one that acts as a radio mirror and is useful for long-distance communication. Shown in Fig. 1 at a height of about 70 miles, it may be anywhere between 55 to 90 miles.

Although the air particles in the E-layer are somewhat less numerous than in the D-layer, the region is still relatively dense; the ions and electrons recombine rather rapidly, and ionization is minimum at midnight. At maximum ionization, near noon, the E-layer, like the D-layer, absorbs energy from low-frequency radio waves. But, unlike the D-layer, the E-layer reflects some radio signals. At high noon, for example, the 80-meter amateur band (3.5–4.0 mc) previously mentioned may be useless because these frequencies are completely absorbed in the D-layer; but the 40-meter amateur band (7.0–7.3 mc), despite some absorption in the D-layer, may provide communication for hundreds of miles due to E-layer reflection.

The F1-layer, at its average height of about 125 miles, exhibits most of the characteristics of the E-layer.

The highest and most useful layer of the ionosphere is the F2-layer which sits at an average height of about 200 miles. Because the air in this region is extremely thin, the ions and electrons in it recombine very slowly. Ionization in this layer, therefore, is not as directly related to sunlight as in the other layers. A short while after noon, the layer reaches maximum ionization. Afterward, ionization gradually decreases to a minimum just before sunrise. The F2-layer acts as a highly effective radio mirror for long-distance communication.

After sundown, the F1-layer combines with the F2-layer, which then drops down in height. Keep in mind that Fig. 1 illustrates a daytime condition.

Radio propagation

Radio propagation using the reflective characteristic of the ionosphere is termed "ionospheric skip" because the signal skips over large areas as it hops on its way. Referring to Fig. 2, note that the skip distance is the distance from the transmitter to the point where the signal again returns to earth. The signal may then be bounced upward to be reflected once more from the ionosphere and thus complete another skip. Such multihop propagation makes world-wide radio communication possible. Because the ionospheric skip signal is reflected from the sky (that is, the ionosphere), this is also called sky-wave propagation.

Obviously, the ionospheric skip signal jumps over certain places and cannot be heard there. If you would like dramatic proof of this, listen in on the 10-meter amateur phone band (28.5–29.7 mc) sometime when it is "open." You'll find that you can generally hear only one side of the conversation—because the sky wave of the other station skips right over your location!

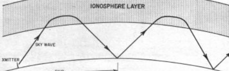

Fig. 2—An example of skip (sky-wave) propagation.

Ionospheric skip or sky-wave propagation is but one type of wave propagation, of course. The rock 'n' roll teenager mentioned at the beginning of this article probably couldn't care less, but it is primarily ground-wave propagation that provides him with the programs of standard broadcast stations. Ground-wave (or surface-wave) propagation refers to waves that cling closely to the earth as they travel. The earth's surface absorbs much of the wave's energy, limiting this type of propagation to about 100 miles for standard broadcast transmissions.

The young child mentioned earlier can enjoy his favorite television program because of line-of-sight propagation, which is just about what the name implies—the waves travel in a rather direct line from the transmitter to the receiver. This type of transmission applies to frequencies from about 30 mc on up; ordinarily the ionosphere does not reflect such waves. If they are directed at the ionosphere, they simply travel off into outer space.

Since signals at frequencies higher than 30 mc go through the ionosphere and on into space, the so-called Age of Space Communications is possible. The missile-tracking expert probably had radio equipment for frequencies from *1,000 to several thousand megacycles* (a megacycle, remember, is 1,000 kc).

While space communications is a very romantic and promising field, ionospheric skip still provides the means for much of the world's long-distance communication, as well as providing radio amateurs and short-wave listeners with fascinating hobbies.

The big problem with ionospheric skip propagation is that it is erratic. For example, certain eruptions on the sun cause ionospheric "storms" and a disturbance of propagation conditions. At other times, mysterious radio blackouts may disrupt communication for a few minutes or many hours.

Since so many variables are involved in ionospheric skip propagation, it is extremely helpful to know the maximum usable frequency (MUF), the highest frequency that can be used for communication over a given path. The MUF for any given transmission path is related to the sunspot cycle in that the MUF tends to be high during sunspot maximum and low during sunspot minimum. Since we are now in a declining sunspot cycle that will probably reach a minimum in the 1962–63 period, you may expect, for the next few years, that the higher short-wave frequencies—say, above 15 mc—will be less and less useful for long-distance communication. Fortunately for all who are interested, several very helpful sources of propagation information are readily available to anyone.

Information sources

Charts that predict the MUF for any transmission path on earth are issued by the Central Radio Propagation Laboratory of the National Bureau of Standards. These charts, called "CRPL-D Basic Radio Propagation Predictions," cover both E- and F2-layer propagation, are issued monthly and provide predictions for 3 months in advance. The cost is 15c per copy, or a year's subscription (12 issues) for $1.50. Circular 465, "Instructions for the Use of Basic Radio Propagation Predictions," tells how to use the charts and costs 30c. Both the charts and circular are available from Superintendent of Documents, US Government Printing Office, Washington 25, D. C.

RADIO-ELECTRONICS publishes a monthly Short-Wave DX forecast which predicts the optimum short-wave broadcast frequencies for the coming month (see page 55). This forecast is prepared from the CRPL-D charts.

Another source of helpful propagation information is the CRPL series Jb' reports issued every Wednesday by the CRPL Radio Warning Service at Boulder, Colo. These weekly reports, issued in postcard form to facilitate mass distribution, include a forecast of geomagnetic conditions based on solar and related data and a record of past geomagnetic activity. Since magnetic disturbance and radio disturbance are strongly correlated, the Jb' reports provide a valuable basis for assessing future propagation conditions.

Send requests for the reports to the CRPL Radio Warning Service, US Department of Commerce, National Bureau of Standards, Boulder, Colo. charge is $4.00 per year in US, Canada or Mexico. All other countries $5.00.

Still another source of reliable propagation information is station WWV, operated continuously by the National Bureau of Standards, Washington, D. C. It operates on frequencies of 2.5, 5, 10, 15, 20 and 25 mc. At 19½ and 49½ minutes after each hour, propagation information applying to transmission paths over the North Atlantic is given in International Morse code. This information consists of a letter. A number, also in code, follows the letter and indicates the expected propagation conditions during the following 6 or more hours. Forecasts are revised four times a day, at 12 midnight, 7 am, 12 noon and 6 pm, EST.

The chart shows the letters and the numbers and their significance, as well as the code for each. The code is sent slowly during these broadcasts. Even if you're a short-wave listener who doesn't know a thing about the code, you'll quickly find that you can make out the propagation forecasts. Remember that the forecast consists of one letter and one number, and this code combination is repeated several times before the call sign and time are given by voice.

Station WWVH in Hawaii, operating on 5, 10, and 15 mc, has similar forecasts for the North Pacific at 9 and 39 minutes after the hour.

So whether ham or short-wave listener, get the CRPL charts and the Jb' reports, check the propagation forecasts on WWV, and then roll up your sleeves and go after those "rare ones." And the best of dx to you, via nature's invisible but wonderful radio mirror—the ionosphere! END

WWV PROPAGATION FORECASTS

Conditions at Time of Forecast

LETTER	SIGNIFICANCE	MORSE CODE
W	Disturbed	dit dah dah
U	Unstable	dit dit dah
N	Normal	dah dit

Expected Reception Conditions During Next 6 Hours

NUMBER	SIGIFICANCE	MORSE CODE
1	Impossible	dit dah dah dah dah
2	Very Poor	dit dit dah dah dah
3	Poor	dit dit dit dah dah
4	Poor to Fair	dit dit dit dit dah
5	Fair	dit dit dit dit dit
6	Fair to Good	dah dit dit dit dit
7	Good	dah dah dit dit dit
8	Very Good	dah dah dah dit dit
9	Excellent	dah dah dah dah dit