Meteor Scatter

A Newly-Discovered Means for Extended-Range Communication in the 15- and 20-Meter Bands

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• Although you might not suspect it, in view of this past winter's experience, the 14-Mc. band is never completely "dead." This article describes a newly-discovered type of propagation that is always present, for which the optimum communication distance is of the order of 800 miles. It has gone undetected for many years because it is usually masked by other forms of propagation and requires first-rate equipment for its exploitation — equipment which, however, is not at all unusual.

Want to keep a schedule with someone seven or eight hundred miles away after the 20-meter band has "gone dead" at night? Thanks to a recent discovery in which amateurs have played a part, it is now possible to do this without shifting down to a lower frequency and battling the usual QRM. By taking advantage of a new type of radio propagation known as "meteor scatter," two stations can communicate far beyond ground-wave range all night long and have the band essentially to themselves.

Furthermore, QSOs can be carried on by this means all day long too, even though the station at the other end is well inside the skip zone at all times. And best of all, here is one type of reasonably long-distance radio transmission which promises not to be subject to fadeouts, ionospheric storms, and all the other uncertainties which plague the regular ionospheric layers. Schedules using this type of propagation should be 100 per cent successful.

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The catch? Yes, there is one, for new types of propagation such as this don't keep themselves hidden all these years without good reason. The disadvantage is that at amateur power levels, it is necessary to be content with a fairly weak signal, and one which fades fairly rapidly between very wide limits. The signal is on the average too weak for satisfactory telephony, but is adequate for c.w. It makes occasional brief dips into the noise, but promptly comes back again. It will often rise twenty or thirty decibels above the noise, for as much as five or ten seconds at a time. The astonishing part of the matter is that the signal — at least *some* signal — is there substantially all of the time, even when the band, by every normal criterion, should be completely dead!

What does one need to take advantage of this form of transmission? Nothing more than an efficient station, and some knowledge of what to expect. Briefly, the explanation of the signal — at least in the vicinity of 20 meters — is forward scattering from ionization trails left behind by the myriads of tiny meteors which pepper the *E* region of the ionosphere at all times. Hence the maximum range for this form of transmission is essentially that for normal one-hop *E*-layer transmission, or 1500 miles. For reasons which will be brought out later, a good transmission distance in practice is about half this value, or around 800 miles.

In view of the low height of the *E* region — roughly 70 miles — the vertical angle of take-off even for the shorter distance is quite low — of the order of 5 or 6 degrees. Thus a good site is a requirement: one which does not have nearby mountains or apartment houses screening off

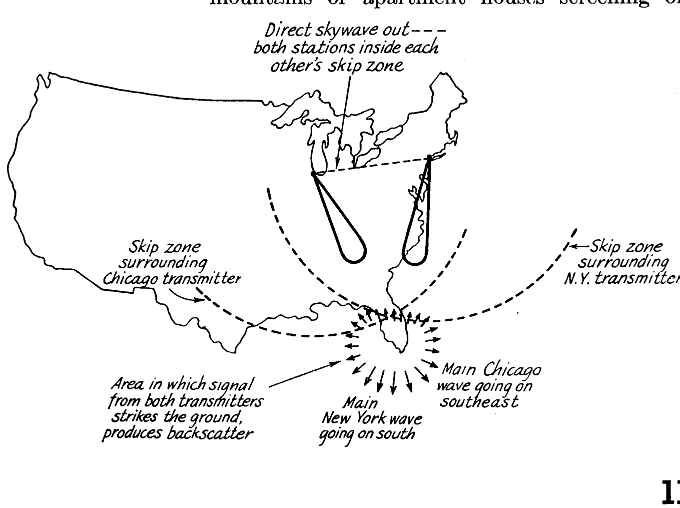
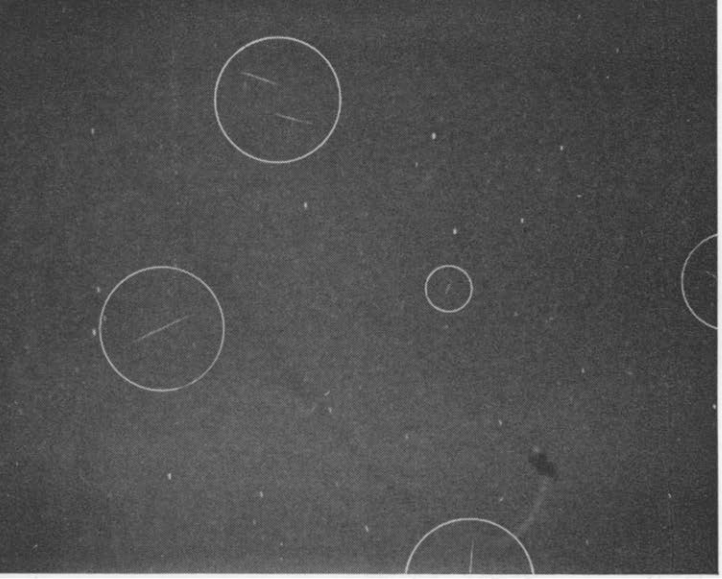


Fig. 1 — Point-to-point communication by ground scattering after layer reflection over the great circle path has failed.



Visible meteors during a shower: a two-second exposure during the great Draconid display of October, 1946. Lines drawn through individual meteor trails (inside circles) intersect at a common point known as the shower radiant. Thousands of meteors too small to be seen — but producing radio reflections — strike the E region of the ionosphere at all times.

low-angle radiation in the desired direction of communication. An antenna well up in the air, a sensitive receiver, and a location reasonably free of man-made QRN are also important. If this sounds formidable, remember that these are no more than the requirements for reasonably good DX results. A "full gallon" is not essential — two or three hundred watts will do, although the more the merrier. It follows that many thousands of operators throughout the country should be able to take advantage of this new type of extended-range transmission.

Ground-Scatter Transmission

How does this type differ from those to which we are already accustomed? The story, briefly, is as follows. Consider two cities, say New York and Chicago, spaced roughly 800 miles apart. (Any other two cities, spaced the same distance would do equally well.) Until fairly recently, it was thought that communication between these two communities at frequencies below 30 megacycles could *only* be conducted when the "regular" layers — F, E and sporadic-E — were sufficiently ionized to reflect a signal from one city to another. The distance involved is much too great for ground- or space-wave communication, and it is also too great for the extension of ground-wave range caused by tropospheric bending, even if that effect were important at the lower frequencies.

Not long ago, however, another mechanism for getting a signal from New York to Chicago in the absence of direct reflection from an overhead layer has come to be understood. This is the indirect bounce by back-scattering from the ground. When the skip is so long that Chicago cannot hear New York directly, both Chicago and New York may still be able to hear Miami, Florida. If the New York transmitter uses a beam directed southward, it will lay down a strong signal all over the state of Florida and the Atlantic Ocean on one side, and the Gulf of Mexico on the other. A small but detectable part of this signal will be scattered in all directions by water waves in the Gulf and the Atlantic, by houses and trees on the land, and so forth. If the Chicago station also uses a beam directed at Florida, it will be able to pick up scattered components of the signal originating in New York, and the two stations will be able to communicate via Florida, as in Fig. 1. The indirect signal will be much weaker than a direct bounce over the great circle path, and will have a hollow, fluttery sound not unlike that of a DX station, but it will be well above the noise level and perfectly readable for both voice and code. (See description on page 74 of the 1953 *ARRL Handbook*.)

This type of scattering has been observed quite regularly by amateurs interested in 50-megacycle DX, and has been given a variety of names including "rebound scattering" and "reflected skip." The authors, who prefer to call it "ground scattering" since this seems to be the more descriptive term, have shown some photographs illustrating it in their article on scatter-sounding in the March, 1952, *QST*.[1] Those photographs show scatter echoes received at the same spot from which the initial signal had been transmitted; it should be understood, of course, that ground scatter echoes from a given transmitter can also be heard at other locations inside the skip zone surrounding that transmitter. Thus a scatter-sounder in New York would be heard in Chicago under conditions of Fig. 1.

Meteor Reflections

Now about the only remaining way to get a signal from New York to Chicago — if we leave out the possibility of bouncing a signal from one place to the other via exceptionally strong auroral ionization to the north — is by means of reflection from a meteor column formed somewhere in the vicinity of the great-circle path.

[1] O. G. Villard, jr., and A. M. Peterson, "Instantaneous Prediction of Radio Transmission Paths," *QST*, Vol. 36, No. 3, pp. 11–20, March, 1952.

It has been thought until recently that these meteor reflections were always of short duration, and of no practical value for communication except perhaps during an exceptionally strong meteor shower such as the great one of October, 1946. This impression has stemmed from the fact that most observations of meteors have been conducted with transmitter and receiver at one location, which is clearly the most convenient experimental arrangement. Under these conditions relatively isolated reflections, or signal bursts, are obtained.

Recent advances in understanding the nature of these reflections, however, have led to some interesting conclusions.[2] It is now known that there are in general two types of meteor echoes. About 10 per cent of the total detected under ordinary conditions have very long durations (ten seconds to ten minutes), strong fading fluctuations, and an irregular and unpredictable "life history." Their behavior is not yet well understood. The other 90 per cent of the echoes have a surprisingly regular behavior, being characterized by a rapid rise to peak amplitude, followed by a decay of exponential form as shown in Fig. 2. Since the decay is exponential, it is convenient to define duration as the time interval between the peak and the time at which the echo strength has dropped to roughly one-third the peak strength. Thus this "duration" is analogous to the time constant of a condenser discharging through a resistor.

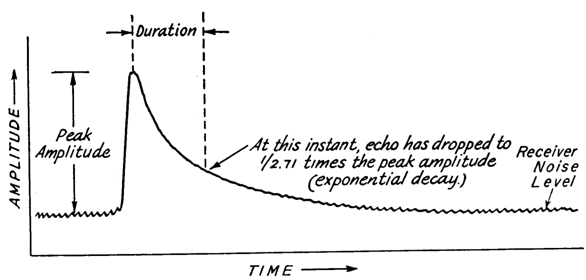


Fig. 2 — **"Life history" of the most commonly-encountered type of radio echo from a meteor trail. Shape is the same for either backward or forward reflection (see Fig. 3).**

Now it turns out that the height of the peak can be predicted quite accurately for this type of echo, and varies inversely as the three-halves power of frequency, assuming all other factors to be held constant. Thus, an echo having a peak of unit strength at 14 megacycles will be less than one-third as strong at 28 megacycles. Furthermore, the *duration* of this type of echo has been found to vary inversely as the frequency squared. Thus if an echo lasts for one second at 14 megacycles, the same echo would last only one-fourth of a second at 28 megacycles.

Lastly — and here is the payoff — it has been discovered that the duration of a meteor echo at any *given* frequency, increases very rapidly when transmitter and receiver are separated by several hundred miles. This increase factor is proportional to the square of the secant of the forward-scattering angle 2ϕ in Fig. 3. It works out that for a transmitter-to-receiver distance of 800 miles, the remote reflection produced by a meteor column formed over the midpoint of the path will have a duration more than *twenty times* that which it would have if the receiver were adjacent to the transmitter.

Thus, by going to a relatively low frequency, such as 14 megacycles, we get stronger echoes, and ones which have longer duration. Then, by changing from a backward to a forward path, we get another increase in echo duration — and quite a large one at that.

For some years, back-reflection experiments have shown that a truly astonishing number of meteor echoes can be received even with relatively low-power equipment. Measurements at Stanford University[3] using equipment and power levels substantially equivalent to that employed in a 1947 amateur experiment[4] have shown that at a frequency of 23.1 megacycles, during the early morning hours, several thousand meteor reflections per hour can be detected. This is at a rate of nearly one per second. The average duration of each echo at this frequency may be taken (conservatively) to be one-quarter of a second. This implies that on the average, meteor echoes are present for nearly one-quarter of the total time.

If now the frequency is lowered to 14 megacycles, and an 800-mile forward bounce is considered, the average duration of the meteor reflections is multiplied by a factor of roughly 50 times! Thus, if one echo occurs each second, and each echo lasts on the average twelve seconds, *there will clearly be more than enough meteors present to guarantee a continuous signal by meteor reflections alone.*

This picture is, of course, greatly oversimplified, although it does represent a fair approximation. For example, the area of the sky from which meteor echoes are obtained for overhead reflection is not the same as it is for distant reflection. However, when all the details are worked out, to the best of present knowledge, there

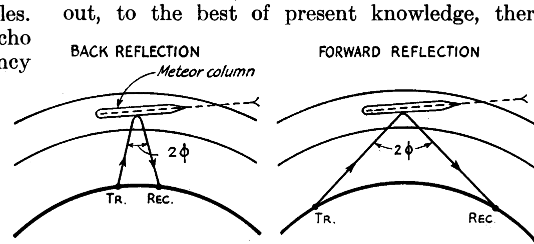


Fig. 3 — **Illustrating backward and forward reflection (or "scattering") from a meteor trail.**

[2] Von R. Eshleman, "The Mechanism of Radio Reflections from Meteoric Ionization," Technical Report No. 49, Electronics Research Laboratory, Stanford University, Stanford, Calif., July 15, 1952.

[3] L. A. Manning, O. G. Villard, jr., and A. M. Peterson, "Radio Doppler Investigation of Meteoric Heights and Velocities," *Journal of Applied Physics*, Vol. 20, No. 5, pp. 475–479, May, 1949.

[4] O. G. Villard, jr., "Meteor Detection by Amateur Radio," *QST*, Vol. 31, No. 7, pp. 13–18, July, 1947.

will be at 14 megacycles enough meteor reflections on the average at *all* times of the day and year to guarantee a continuous signal between two amateur stations separated by 800 miles and having moderate transmitter powers, good locations, and simple beam antennas.

Accidental Discovery

This effect was turned up accidentally by the authors during the course of the W6YX scatter-sounding experiment,[1] which consisted of a demonstration that when echoes from a particular area appear on the scatter-sounder, strong signals can actually be heard from amateur stations located in that area. The converse, of course, was also investigated at the same time. In other words, the authors were just as eager to be able to show that when *no* echoes appeared from a given area, amateur signals could *not* be received from that area, either. This proved to be a tricky proposition, as was pointed out, because as long as any echoes appear anywhere on the indicator, it is always possible for a station in a supposedly "dead" region to be heard weakly by ground scattering via the area from which the echoes are coming.

It was decided that the most convincing test would be to wait until late on a night after all *F*, *E*, and sporadic-*E* activity had disappeared, and the indicator showed no echoes at all. Such nights are actually few and far between on the West Coast during the months of November and December. When one was at last found, a 'phone call was put through to Rod Beaudette, W7FXI, at Spokane, Washington, about 750 miles airline from Palo Alto. Rod, a Stanford graduate who had participated in the early meteor experiments at W6YX, has 500 watts on the air feeding a 3-element beam perched 30 feet above the roof of his house in suburban Spokane. At his location the ground slopes off toward the south (the direction to Palo Alto), and there are no intervening mountains to block off the horizon. Aside from this, Rod's location might be termed average, having the usual number of impedimenta in the form of light lines, neighboring houses, etc. W6YX's location (at least for the north and south directions) is better than average; the station is located atop a small hill one or two hundred feet above the floor of the valley containing San Francisco Bay.

While Rod, wakened out of a sound sleep, good-naturedly went down into his basement to turn on the rig, we at Palo Alto thoroughly crossed our fingers and patrolled back and forth across an absolutely dead band. Suddenly, a signal! Could that drowsy-sounding voice be Rod's? In our excitement, we placed another 'phone call to verify it. There could be no doubt. Again we checked the amateur scatter-sounder. No sign of any echoes. No sporadic-*E* at all, and *F*-reflections had died out hours earlier. Yet there was W7FXI: at times unreadable on voice — at others, easily readable and well above the noise. During the dips, his carrier could always be copied by switching on the b.f.o. C.w. reception was quite satisfactory without the crystal filter, and much improved, of course, with it.

These tests were repeated as often as suitable conditions could be found, with similar results on each occasion. The signal was definitely always there, when by all rights nothing should be heard. Its characteristics at once suggested the meteor-scatter explanation, and instantaneous field-intensity recordings strengthened this impression. In addition to bursts, nose whistles and "body Dopplers" could easily be seen superimposed on the continually-fading, but almost-always-present background. As is to be expected, the duration of the big bursts over this long path was, on the average, far greater than anything we had experienced during the course of local tests. Fig. 4 illustrates this effect by showing the comparison between a recording of backward-reflected meteor echoes obtained locally, and a similar recording of forward-reflected meteor echoes over a 750-mile path. Echo overlapping in the latter case prevents accurate determination of individual echo durations but the increased average duration is clear.

Other Paths

In the thought that there might be something magic about the path to Spokane, similar tests were carried out with W7PZ in Tucson, Arizona — about 750 miles away in a southeasterly direction. Ben has a three-element beam, about 300 watts, and a location outside Tucson on flat land not far from the airport. His signals were heard just as consistently as W7FXI's in Palo Alto.

In addition, W6HJT in San Marino — only 300 miles away and nearly south from Palo Alto — also put in a very strong signal with a steady background underlying the meteor bursts.

Attempts to increase the frequency or the distance met with less success, however. Transmissions to and from Tucson on 10 meters resulted in a signal audible only during well separated bursts, with no sign of a background between.

On one occasion, WØPRZ in Aberdeen, South Dakota, was asked to listen for the 20-meter W6YX signal. His dis-

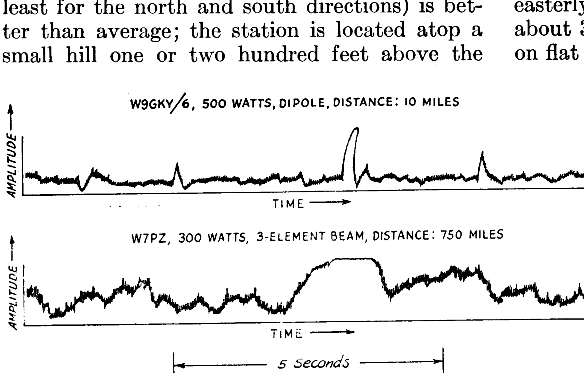


Fig. 4. — **Forward and back-reflected meteor echoes at 14 megacycles. When these records were made (late at night), no layer propagation of any kind could be shown to be present.**

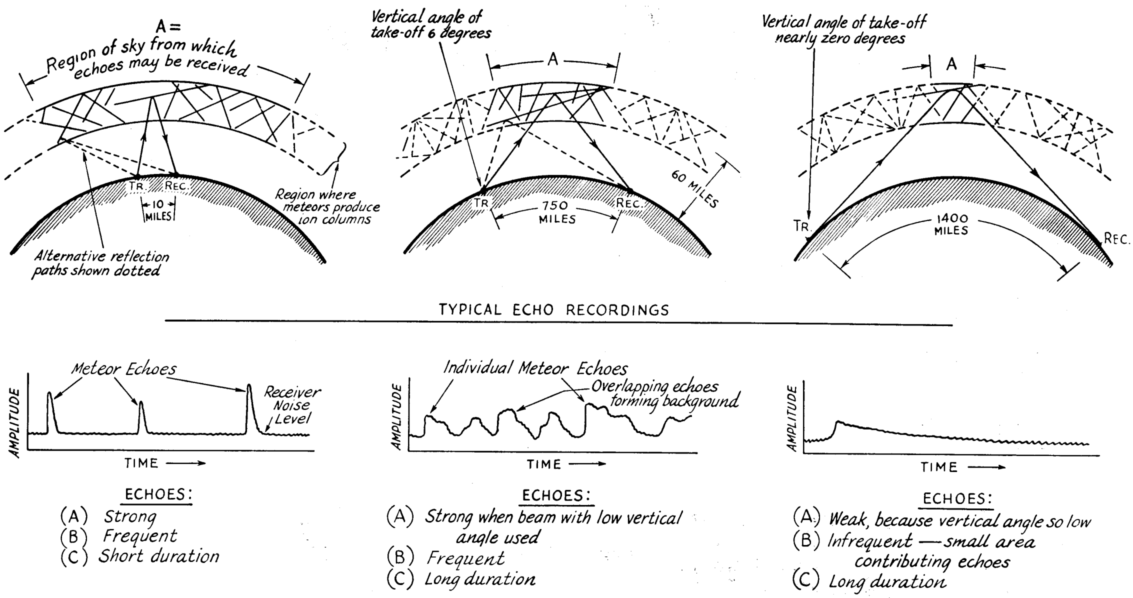


Fig. 5 **— Effect of distance on meteor echo behavior, for a given frequency and power.**

tance is near the maximum for one-hop *E*-layer reflection: about 1400 miles. During the course of a 15-minute transmission, only one or two distinct bursts were heard. His antenna, location and equipment are top-flight, as his DX record shows, so the conclusion seems to be that at extreme range the number of meteors which *can* produce a signal over the path (they have to be just about exactly over the midpoint) becomes so small that a continuous background is not supported. Also, the angle of take-off becomes so low (down around one degree) that antennas of practicable height are quite inefficient. The effect of varying transmitter-receiver distance, with frequency and power constant, is shown in Fig. 5.

Relationship to 50-Mc. Scattering

The theoretical investigations which followed these ham experiments confirm the expectation that meteors alone can support the entire signal.[5, 6] However, the possibility that other factors may be involved can by no means be ruled out. There has recently been published an account of another new form of propagation, in many respects resembling that discussed in this article, which is effective at frequencies of the order of 50 megacycles and at very high power levels.[7] It is suggested that this propagation may be explained as forward-scattering from irregularities such as might be caused by turbulence in the *E* region of the ionosphere. Meteors are cited as playing an important part. The observed signal, however, has certain characteristics for which meteors would almost certainly not be responsible.

These characteristics, unhappily, are not easy to study at 15 megacycles. It is not yet known to what extent, if any, the 15- and 50-megacycle signals are caused by the same agency. The situation as of December, 1952, may be summarized in the following way. At the lower frequency, theory indicates that meteors alone should easily account for the observed signal. Nothing in the experimental evidence thus far disagrees with this conclusion. At 50 megacycles, however, the theory — based on present knowledge of meteor echo behavior — predicts that they alone will not be sufficient to account for what is observed. It appears that other factors must be sought.

The unscrambling of the several factors which may contribute to the signal observed at the two frequencies will be an exciting and challenging job. One of the first tasks will be to gain as much experience with these new types of propagation as possible. Here the amateurs, with their wide geographical distribution, and their willingness to experiment at all hours of the day and night, are in a position to make a real contribution. It is obvious that any means for making the 20-meter band work around the clock (at least for 800-mile QSOs!) is going to be important as crowding on the lower frequencies increases. Furthermore, the invulnerability of meteors to ionospheric storms is another important point: a weak, but *really* reliable circuit may, during emergencies, be worth much more than one which could fade out at the crucial moment.

(Continued on page 124)

[5] O. G. Villard, jr., A. M. Peterson, et al., "Extended-Range Radio Transmission by Oblique Reflection from Meteoric Ionization," *Journal of Geophysical Research*, March, 1953 (in press).

[6] Von R. Eshleman and L. A. Manning, "Radio Communication by Scattering from Meteoric Ionization," Technical Report No. 57, Electronics Research Laboratory, Stanford University, Stanford, Calif., December 1, 1952.

[7] D. K. Bailey, et al., "A New Kind of Radio Propagation at Very High Frequencies Observable over Long Distances," *Physical Review*, Vol. 86, pp. 141–145, April 15, 1952.

Meteor Scatter

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Signal Strength

The strength of the meteor-scatter signal, and hence its usefulness in ham communication, will depend on the efficiency of the stations involved. The antenna system is very important, and should be designed to concentrate power where the most meteor scatter is taking place — namely, in the *E* region over the mid-point of the great circle path. For an 800-mile path, the main lobe of the pattern in the vertical plane should ideally be at 6 degrees above the horizontal. At 20 meters a dipole should be 165 feet over perfectly-conducting earth, for the lowest lobe to be at 6 degrees! In practice, whatever arrangement affords the highest gain consistent with a low vertical angle will be best.

Almost any good station will be able to take advantage of meteor-scatter transmission at 20 meters. At 15 meters, however, it is probable that only the kilowatt boys will be able to transmit a usable background signal over the path. Stations having good locations and rotary beams (or preferably rhombics), and willing to use maximum receiver crystal selectivity, will no doubt be able to make a go of it. (As frequency goes up, echo strengths and durations go down, but since the echoes are exponential, the net loss can be overcome by an increase in power or receiver sensitivity.) In any case, a c.w. clipper or limiter will be very worth-while. Otherwise, when gain is advanced enough to copy weak passages, meteor bursts tend to be deafening.

Note that the preceding remarks on signal strength apply to those times of day when meteor scatter is the *only* form of transmission taking place. Actually, for much of any given day the signal will be well above the purely meteor level. Any sporadic-*E* activity, for example, will enormously increase the strength of the received field. (During one memorable test with W7PZ, sporadic-*E* set in and within a minute or so transformed his randomly-fading S1 meteor-scatter transmission into a rock-solid S9 signal with a very slow, almost perfectly sinusoidal amplitude variation.) Whenever any *F*-layer transmission is in at all, of course, there will be a strong ground back-scatter component present along with the meteor-scatter.

Thus the timetable for 14-Mc. transmission over a New York-Chicago path, during the winter months of the year, might run something like the following:

8 P.M. — 7 A.M.	meteor scatter alone	weak signal
7 A.M. — 9 A.M.	meteor plus *F*-layer ground scatter	medium signal
9 A.M. — 5 P.M.	direct *F*-layer transmission	very strong signal
5 P.M. — 8 P.M.	meteor plus *F*-layer ground scatter	medium signal

(Sporadic *E*, which might come in at any hour

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of the day or night, would provide a strong signal directly, or a weaker signal via ground scatter.)

Commercial Stations

The reader is probably wondering, at this point, why meteor-scatter propagation has not previously been noticed on transmission from commercial stations. The answer is that it probably has, but simply was not identified as such. Most broadcast or commercial stations are in the habit of signing off after *F*-layer transmission fails, so listeners seldom get much of an opportunity to hear meteor scatter. Once in a while a station, transmitting according to a prearranged schedule, will stay on the air after its frequency has "gone dead." This has happened, for example, in the case of a 17-megacycle short-wave broadcasting station roughly two hundred miles south of Palo Alto. Their beam points right at Stanford, on its way to the Orient, and what is believed to be meteor scatter has been heard on many occasions.

WWV's transmissions on 15 and 20 megacycles, of course, provide a wonderful opportunity to check for meteor scatter, and hams living within a radius of 1000 miles of Beltsville, Maryland, are urged to tune in on WWV and satisfy themselves that the 20-meter band really doesn't go entirely dead, at night, after all!

Acknowledgment

The authors are indebted to W6VUW, W6UGL, W6LLK, W6AOF and other members of the Stanford Radio Club for assistance during the tests. The help of Larry and Clayte at W7TMK is also appreciated. The loan of recording equipment belonging to a joint-Service-sponsored research project is gratefully acknowledged. The photograph of meteors during a shower was taken by L. A. Manning, W6QHJ.

YL News & Views

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who works ten LARK members. Send members' calls and dates and frequencies of the QSOs to Gladys, W9MYC. The LARK now meet at 1400 CST on Wednesday (10 meters) each week, except the first week of the month when they meet at 2200 CST on Tuesday.

April eleventh is the date of the semi-annual W1 YL Luncheon (YLRL members and nonmembers alike). The place is the Smith House in Cambridge, Massachusetts. Write Helen Wright, W1UPZ, P. O. Box 126, Brookline 46, Mass., for further information.

Wava Harlan, W8FPT, is the YLRL District Chairman of the eighth call area. First licensed in 1950, Wava is active on 10, 20 and 75. Her OM is W8EAM. Since the start of her term last July, Wava regularly has sent postcards to each of the licensed YLs in her district, in quest of information and news. Other DCs who follow this practice find it's worth the little extra time and effort.