Ground conductivity measurements

by K. N. STOKKE

WHEN we want to measure ground constants, there are several conditions which have to be taken into account. For instance, we have to use a suitable frequency and a measuring method which will give reliable results under the circumstances in which the measurements are to be carried out.

Concerning the measuring method, one of the difficulties is that the influence of the ground in one part of the path follows the electromagnetic wave all the way. For example, a good or a bad start for the ground-wave will be of great importance for the behaviour of the wave. Especially when there are several changes in the ground constants, it is important to know the whole "history" of the wave.

When we want to measure the ground conductivity, the attenuation method is one of the most reliable because it takes into consideration all that has happened to the wave. However, when using the attenuation method, it is important to know the effective radiated power (e.r.p.) from the antenna at the transmitting station. The cymomotive force method is convenient to use when we want to measure the radiated power in any direction from an antenna. If we have a single vertical radiator, we should expect to have non-directional antenna patterns and, normally, it is sufficient to measure the radiated power only in one direction (radial) from the transmitting antenna. However, it may be advantageous to measure along two or three radials and take the mean of these measurements.

When we have a directional transmitting antenna, it is necessary to know the radiated power along each of the radials where we want to measure the ground conductivity.

The cymomotive force (c.m.f.) is the field strength E multiplied by the distance r from the transmitting antenna:

$$\text{c.m.f.} = E \cdot r$$

If we refer to a short monopole and transmitter power $P = 1$ kW, we have:

$$E = \frac{3\sqrt{10\,P}}{r} = \frac{3\sqrt{10 \cdot 1000}}{r}$$

$$= \frac{300}{r}\ (\text{V/m})\ \left(= \frac{3 \cdot 10^5}{r(\text{km})}\ (\mu\text{V/m})\right)$$

For 1 kW e.m.r.p. (effective monopole radiated power) and a perfectly conducting plane we therefore have:

$$\text{c.m.f.} = \frac{300}{r} \cdot r = 300\ \text{V}$$

that is, independent of the distance r.

For a transmitting station with e.m.r.p. in kilowats we have:

$$\text{c.m.f.} = 300\sqrt{\text{e.m.r.p.}}\ \ (\text{kW})$$

$$\text{e.m.r.p.} = \left(\frac{\text{c.m.f.}}{300}\right)^2 (\text{kW})$$

In practice, we never have a perfectly conducting plane. With a certain conductivity σ, the c.m.f. may vary with the distance as indicated in figure 1.

We, therefore, have to measure the field strengths E at some distances r. A curve may be drawn through the c.m.f. points and prolonged to the antenna site where the c.m.f. of the transmitting station in that direction is found.

However, in many cases the conductivity σ also varies. Therefore, the cymomotive force curve is not as smooth as shown in figure 1. It is often necessary to measure the curve from about 1λ and up to 15λ or more in order to get enough information about the variations. To measure the c.m.f. curve nearer than 1λ to the transmitting antenna is of no use because of the near fields and the dependence on the type of antenna.

The mean of the measured curve is prolonged to the transmitting antenna where the c.m.f. is found, as indicated in figure 2.

The example in figure 2 gives a c.m.f. of 6600 V, and the effective monopole radiated power therefore is:

$$\text{e.m.r.p.} = \left(\frac{6600}{300}\right)^2 = 484 \text{ kW}$$

When we then know the e.m.r.p. of the transmitting antenna, we can continue to measure the field strength curves in radials from the antenna. For these curves we may also use some of the measurements we already have when measuring cymomotive force. The measured curves may now be used to find the conductivities along the radials.

However, as we see in figure 3, the waves from the antenna have to travel some distance before the influence of the ground has been stabilized. Therefore, it is very difficult to get reliable results for ground constant measurements near the transmitting antenna. We should be at least 10λ from the antenna in order to have usable results. This may also be seen from the curves in CCIR Recommendation 368.[1]

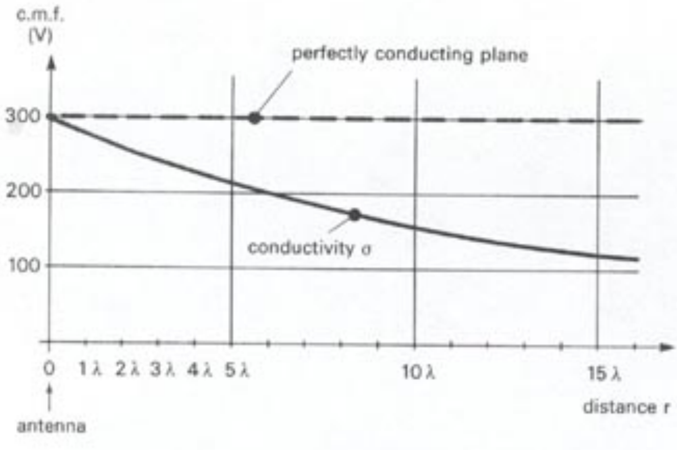

Figure 1—Variation of c.m.f. with distance at constant conductivity σ and 1 kW e.m.r.p.

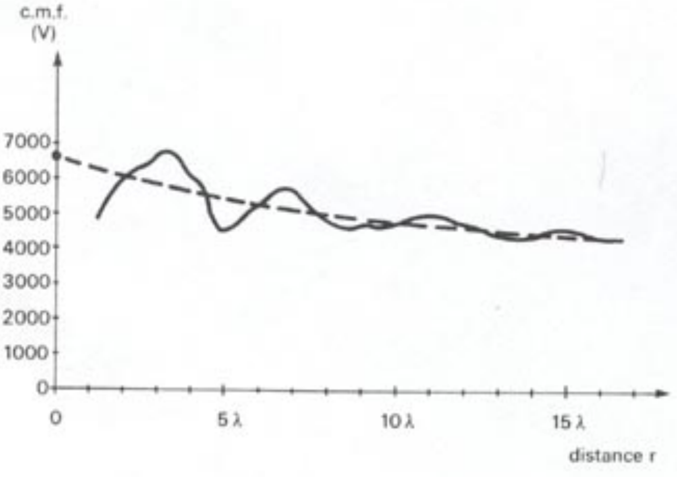

Figure 2—Cymomotive force curve when the conductivity varies

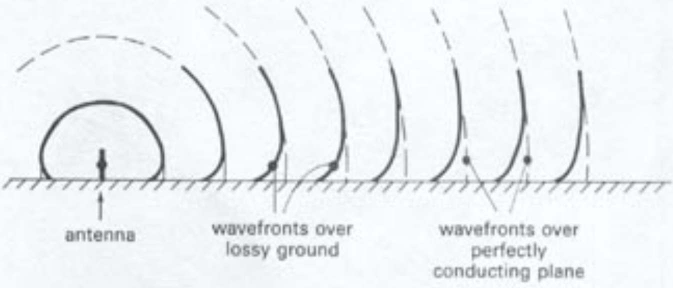

Figure 3—Radiation of ground-waves

To use the attenuation method is in fact to use Millington's method backwards. We may then use a computer and compare the measured curve with Millington's method. We may also employ the simplified graphical method [1-2] if we want to make direct manual comparison.

In order to use the attenuation method, it is necessary to have field strength curves for different conductivities in the frequency range where the measurements are made. In CCIR Recommendation 368 two examples are given, one for low frequencies and the other for medium frequencies. However, it is advantageous to have such curves for more detailed frequency ranges. They are given in the CCIR Report to the First Session of the Regional Administrative MF Broadcasting Conference (Region 2), and may later on also be reprinted in the Atlas of ground conductivities (CCIR Report 717-1).

The field strength curves are normally refered to 1 kW e.m.r.p., and we therefore have to refer our measurements to 1 kW e.m.r.p. If, for instance, we have a station with 484 kW e.m.r.p., we have to subtract 484 kW/1 kW = 26.8 dB from the measured values.

The measured field strength curve, referred to 1 kW e.m.r.p., is drawn on a copy of the curves for the actual frequency range, as shown in figure 4. We may now choose the details we want for the results. In figure 4 it is also shown how we may adapt the Millington curve (simplified method) to the measured curve. As described in references [1-2], the asymptote for the Millington curve after a conductivity change is a distance *m* away from the field strength curve for the conductivity after the change (*m* is the distance to the geometric mean or half the distance in decibels between the field stength curves for the two conductivities at the change). At two times the distance from the transmitting antenna to the change, the Millington curve passes through the geometric mean between the field strength curves.

By using the Millington's method backwards we may now find the conductivity values or the "conductivity curve", as also indicated in figure 4. We can see that the changes in the "conductivity curve" are much more abrupt than the changes in the measured field strength curve.

Concerning the frequencies to be used for ground constant measurements, low frequencies (LF) and medium frequencies (MF) will be convenient. The lower part of the high frequency (HF) band may also be used. To use higher frequencies than 8-10 MHz may give extra problems because of reflections and other influence from the surroundings.

It is not always necessary to make new measurements in order to obtain values for the conductivity in an area. Earlier measurements may also be used. As indicated in figure 5, field strength measurements may have been performed in order to see if a transmitting station gave the expected results. Such

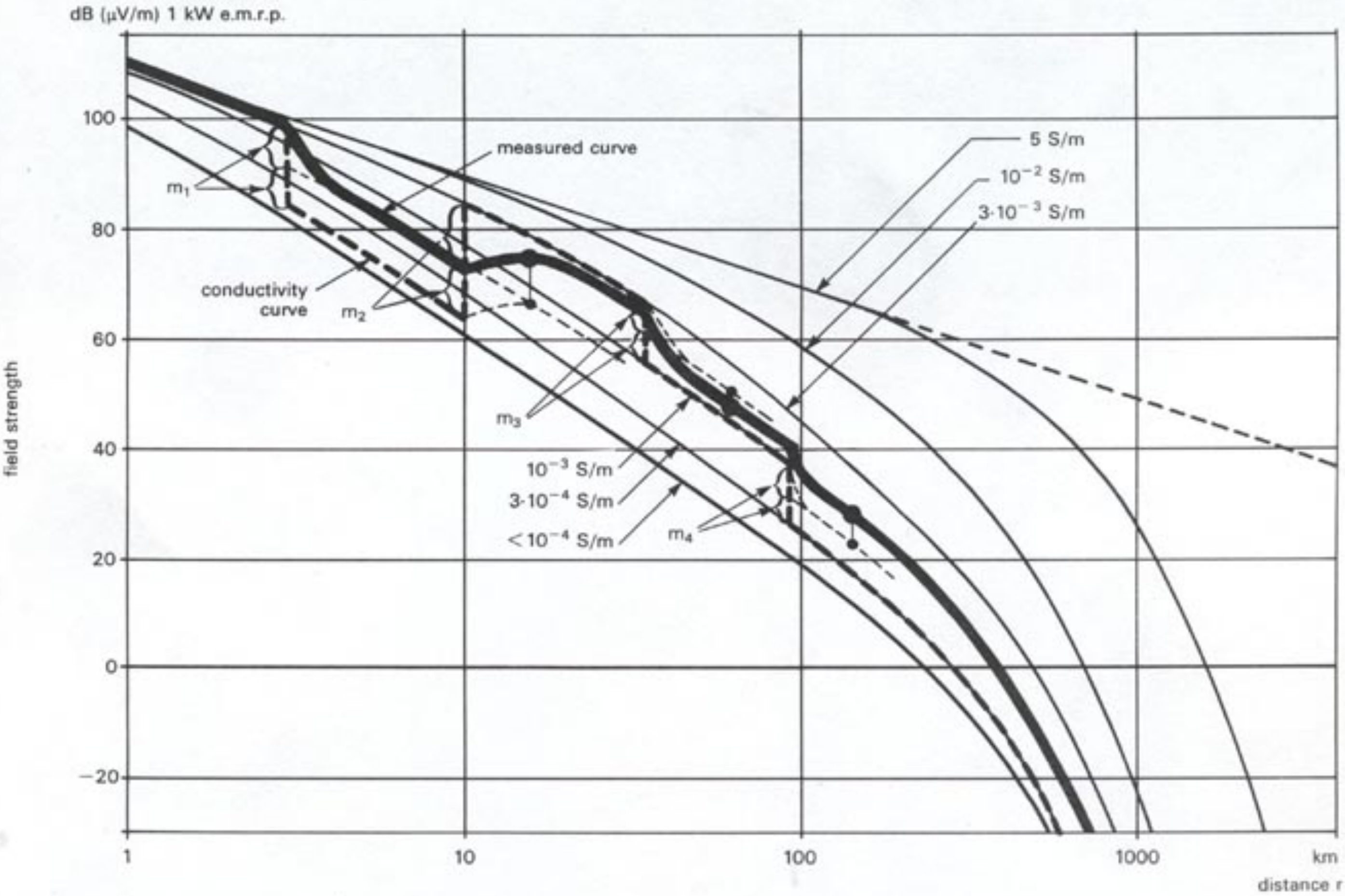

Figure 4—Measured field strength curve drawn into the curves for different conductivities in the actual frequency range

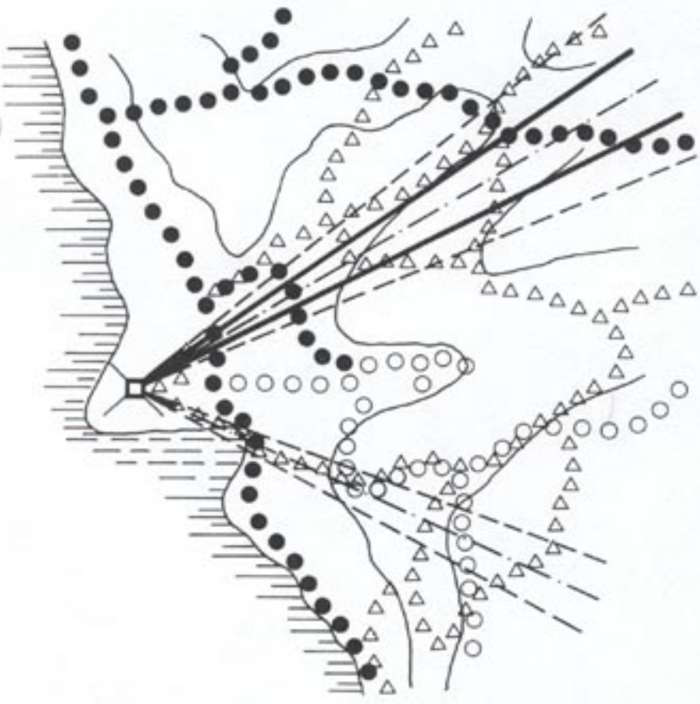

Figure 5—Use of existing measurements

measurements are seldom made along radials, but this may be overcome by using the values in more or less narrow sectors. The values near the transmitting antenna may also be used to find the e.m.r.p. of the station. When we want to have an oversight conductivity map for a country, this method may give quite acceptable results.

In order to control the conductivity values, it is an advantage if some of the measured paths from the different transmitting stations traverse each other. Then we will also have an opportunity to adjust the border lines between the conductivity values.

(Original language: English)

References

[1] CCIR: Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz. *Recommendation 368-4,* Vol. V (Geneva, 1982)

[2] Stokke K. N.: Problems concerning the measurements of ground conductivity, *EBU Review — Technical,* June 1978, No. 169

[3] Stokke K. N.: *Radiotransmisjon* (in Norwegian), Universitetsforlaget, Oslo

---

Author

Knut N. Stokke works in the Regulations Office of the Norwegian Telecommunications Administration on matters related to radio wave propagation. He has participated in the work of CCITT Study Group 5 since 1965 and is also a member of the Interim Working Party 5/1.