New Challenges in the Understanding of Surface Wave Propagation

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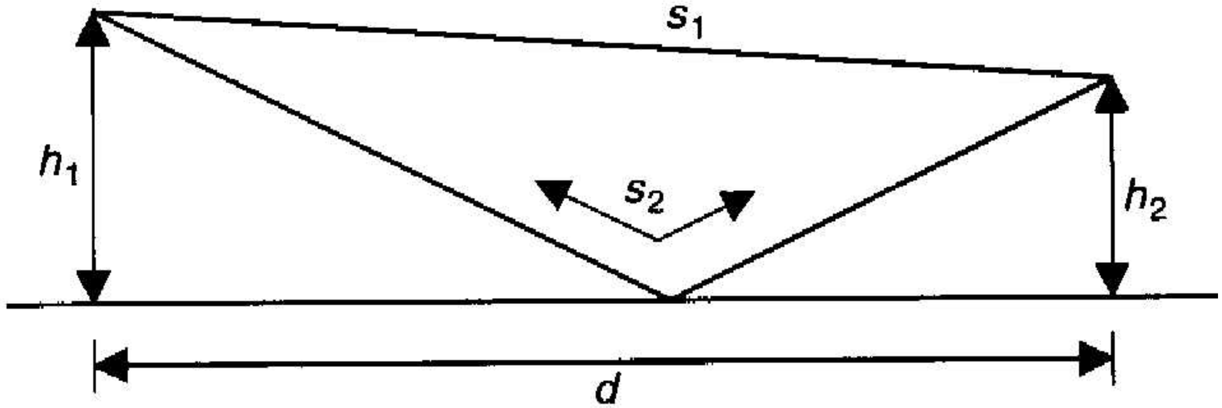

$$V = QI\left\{Q_1 \cdot \frac{\exp(-jks_1)}{r_1} + Q_2 \cdot \frac{\exp(-jks_2)}{r_2}\right\}$$

$$V = QI\left\{Q_1 \cdot \frac{\exp(-jks_1)}{r_1} + Q_2 \cdot \frac{\exp(-jks_2)}{r_2} + S\,\frac{\exp(-jks_2)}{r_2}\right\}$$

ground wave = direct wave + reflected wave + surface wave

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space wave

Somerfeld

Van der Pol and Bremmer

Norton

Rotheram - GRWAVE

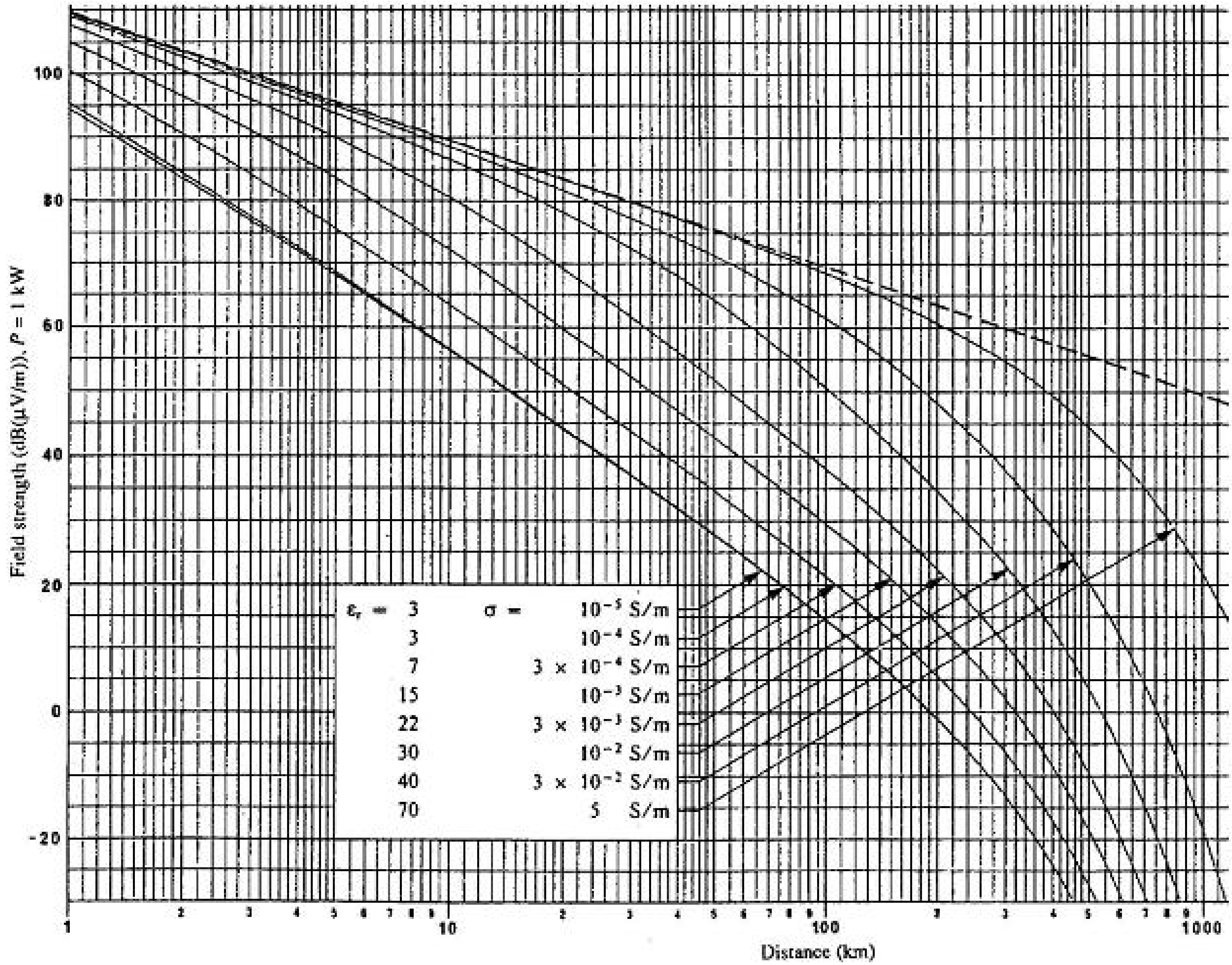
Somerfeld

Zenneck

Van der Pol and Bremmer

Norton

Rotheram


Field strength (dB(μV/m)), P = 1 kW
100
80
60
40
20
0
-20
1
10
100
1000
Distance (km)
εr = 3 σ = 10⁻⁵ S/m
3 10⁻⁴ S/m
7 3 × 10⁻⁴ S/m
15 10⁻³ S/m
22 3 × 10⁻³ S/m
30 10⁻² S/m
40 3 × 10⁻² S/m
70 5 S/m

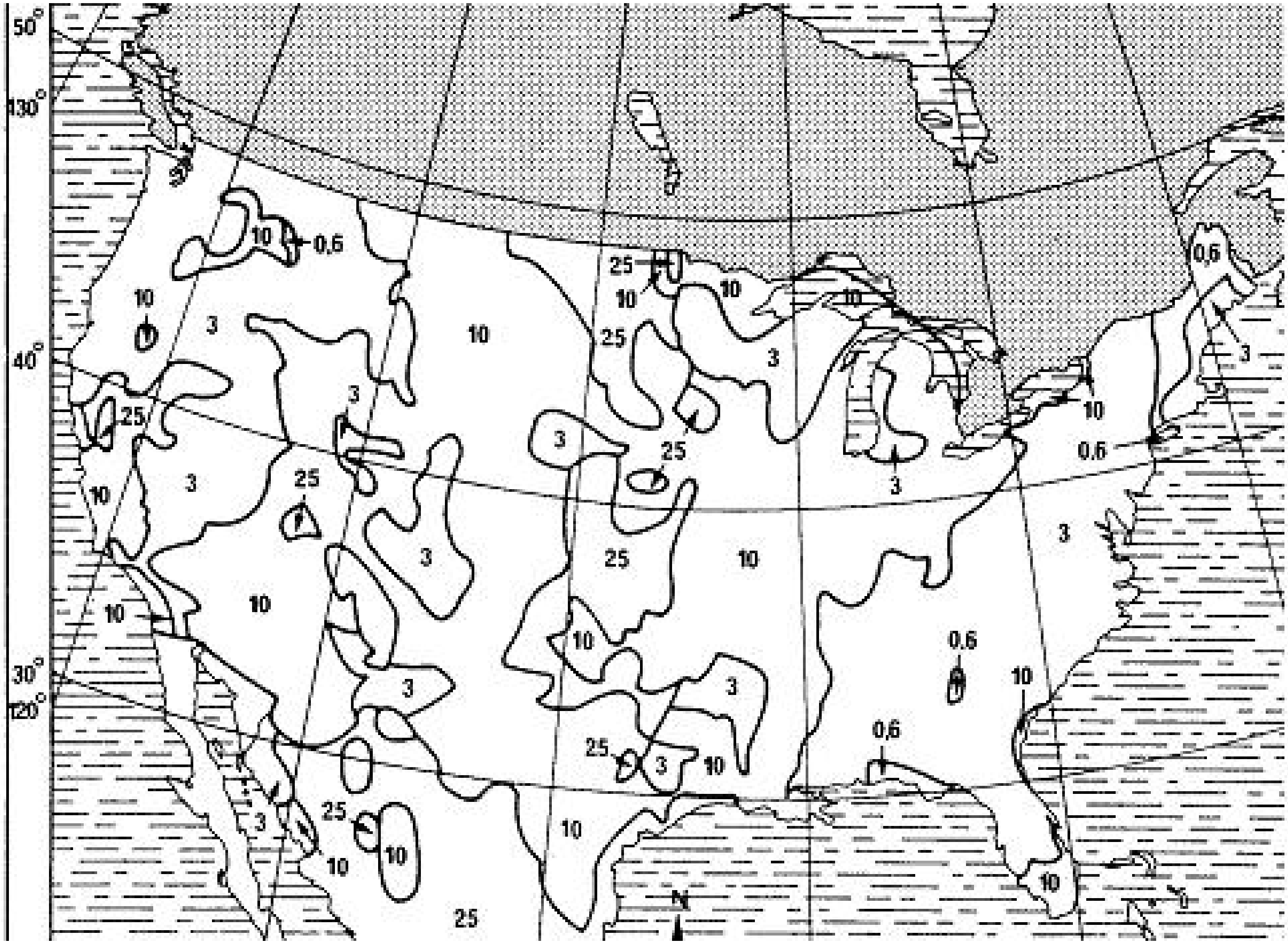
Norton provided a graphical method of modelling the surface wave around a homogeneous smooth earth by means of a complex attenuation function.

There are both vertical and radial components of the electric field, so that the wave front is tilted forward and there is attenuation due to losses in the ground.

The attenuation function in the surface wave equations includes a term

$$u^2 = \frac{1}{\varepsilon_r - 60\sigma\lambda}$$

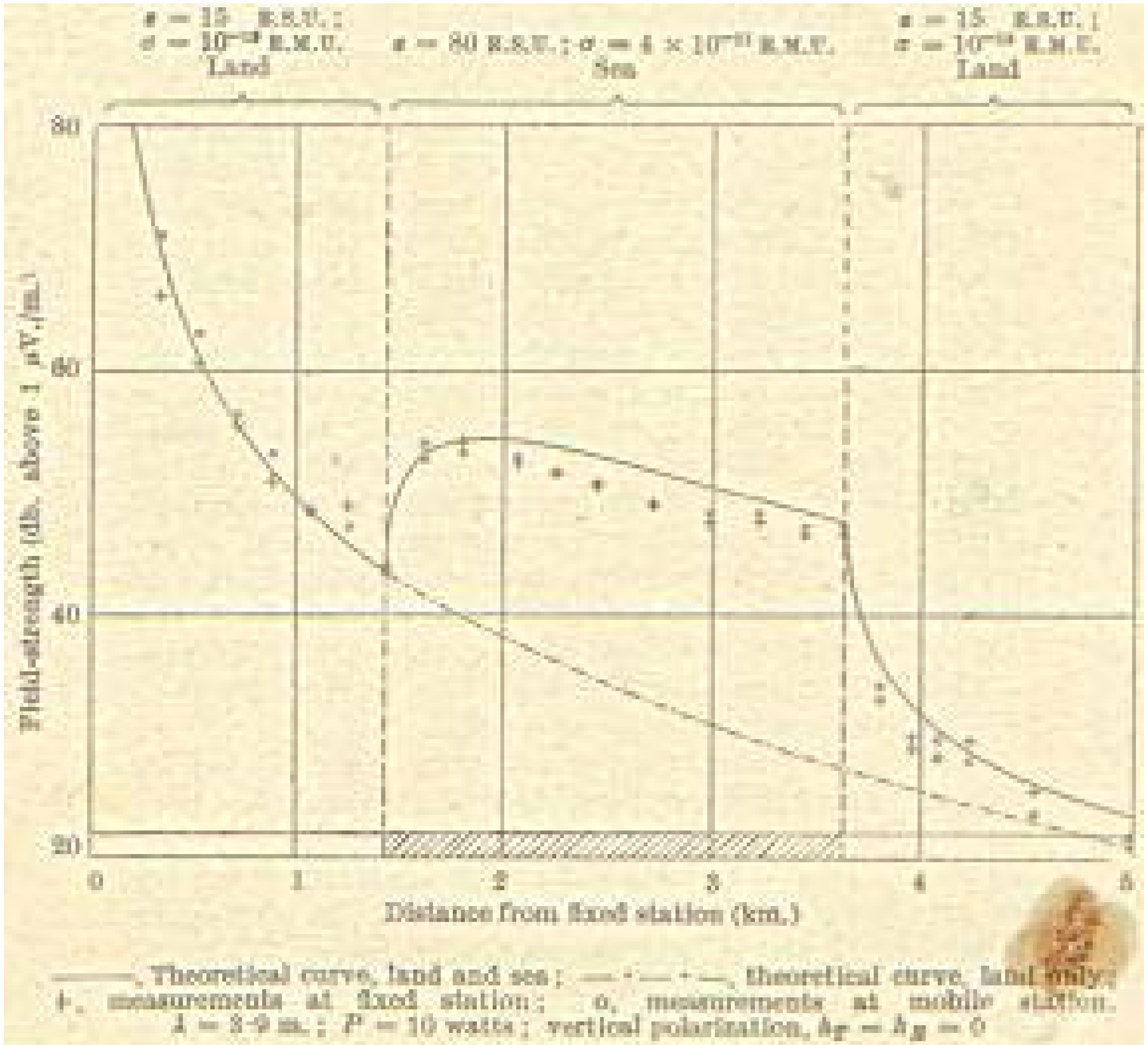
Ground type	Frequency	
	200 kHz	1MHz
Sea	70-j450,000	70-j90,000
Good ground	10-j900	10-j180
Poor ground	4-j90	4-j18


50°
130°
40°
30°
120°
10
0,6
3
25
N

The effective conductivity may vary with frequency, dependent on the penetration depth and on sub-surface strata.

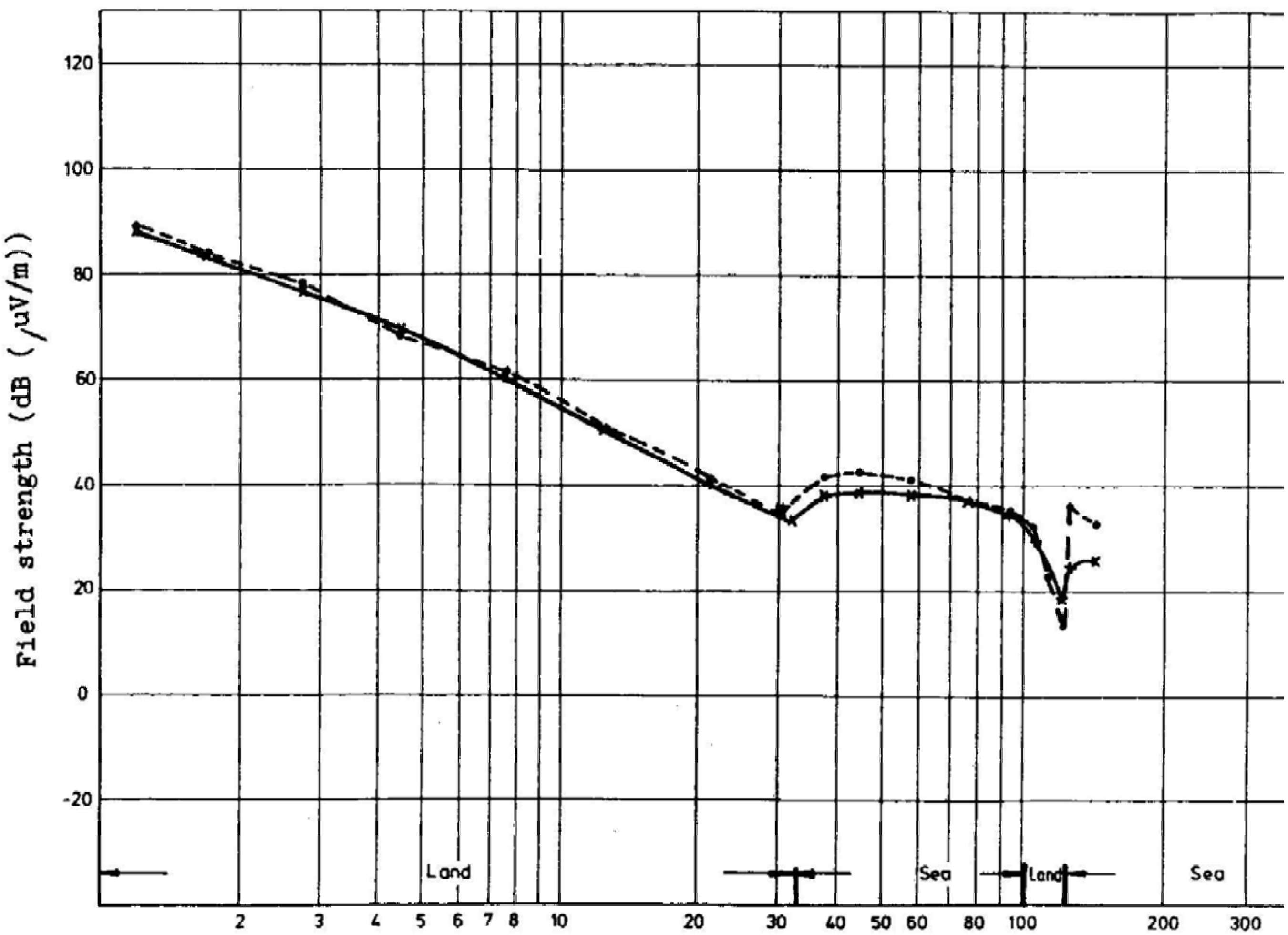
But changes in conductivity along the path have a significant effect.

The empirical Millington method, forces reciprocity and has proved to be equivalent to theoretical methods over smooth earth.


Land
Sea
Land
80
60
40
20
0
1
2
3
4
5
Field-strength (db. above 1 μV./m.)
Distance from fixed station (km.)
——, Theoretical curve, land and sea; —·—·—, theoretical curve, land only;
+, measurements at fixed station; o, measurements at mobile station.
λ = 3·9 m.; P = 10 watts; vertical polarization, h = h = 0

MF measurements across the English channel also produced the expected results.

But the increase over sea seems so unlikely that newcomers to the topic will doubt it.

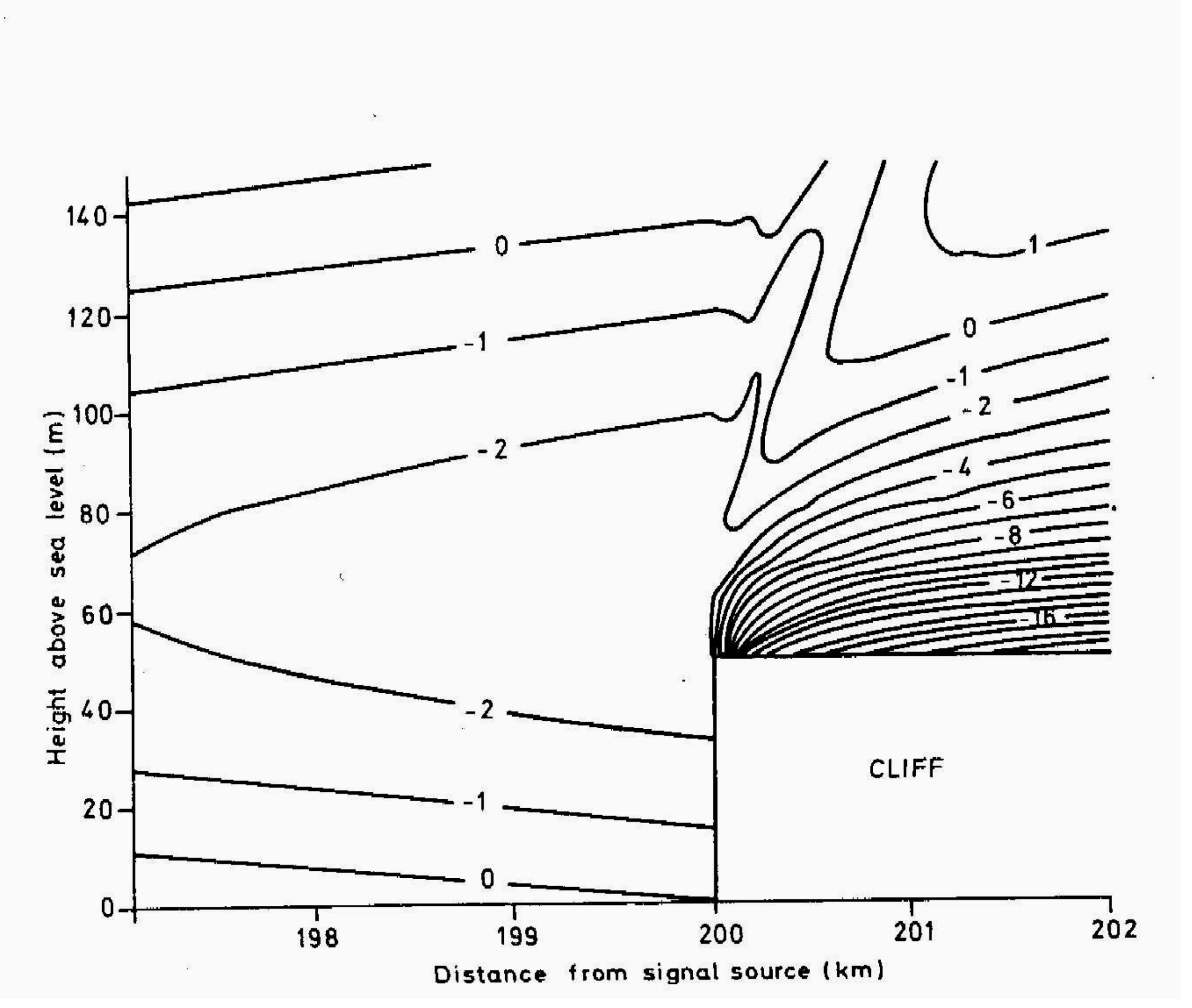

Field strength (dB (µV/m))
120
100
80
60
40
20
0
-20
Land
Sea
Land
Sea
2
3
4
5
6
7
8
10
20
30
40
50
60
80
100
200
300

Ground height irregularities where the slopes are gentle and height changes are comparable with the wavelength may not be important for area planning purposes; it would not be easy to distinguish between field strength variations due to changes in height or in conductivity.

As we heard yesterday local features may give important changes but these are likely to be built into a planning margin, taking account of the probability of occurrence of local features, rather than in the overall coverage planning .

A full integral equation method of dealing with terrain irregularities was developed by Hufford and Ott developed a related computer method.

Furutsu developed a method for dealing with path segments with different conductivities and different heights



140
120
100
80
60
40
20
0
Height above sea level (m)
198
199
200
201
202
Distance from signal source (km)
0
-1
-2
-2
-1
0
1
0
-1
-2
-4
-6
-8
-12
-16
CLIFF

With enough theoretically based long standing methods surface wave propagation seems well understood.

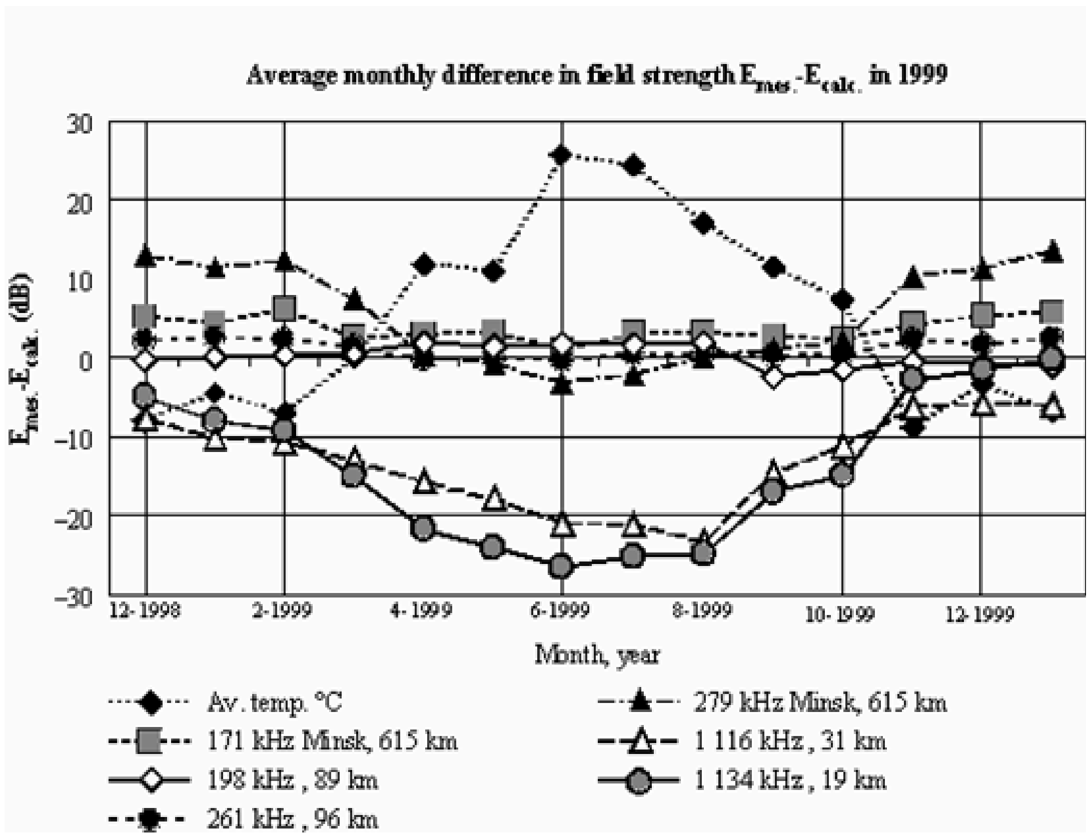
It provides a proven basis for frequency planning. There's enough information to provide guidance for surface wave radars.

It enabled the introduction of commercial MF broadcasting in the UK.

BUT

Variation with temperature

There have been several papers and ITU-R contributions from Russia reporting a variation of ground wave field strength with temperature.



Temperature is not a parameter in the theory.

There could be seasonal changes in ground conductivity, but these are more likely to be related to water content rather than temperature.

Ice is a low loss dielectric (Piggott and Barclay 1962), but ground freezing might be expected to have a time lag with temperature.

May be due to trees freezing or snow cover on trees.

Proposals made for research elsewhere to seek to replicate the results, judged good proposal but not funded

ITU-R Recommendations are meant to “recommend” and provide clear and general guidance.

Recommendation P.368-9 now contains:

"The average annual difference between winter and summer monthly median field strengths, for 500-1 000 kHz, ranges between 5 dB (where the average Northern Hemisphere January temperature is +4°) and 15 dB (where the average Northern Hemisphere January temperature is –16°)".

Does not give clear guidance

Seems to relate to all of the northern hemisphere with appropriate temperatures

Seems to apply at all ranges

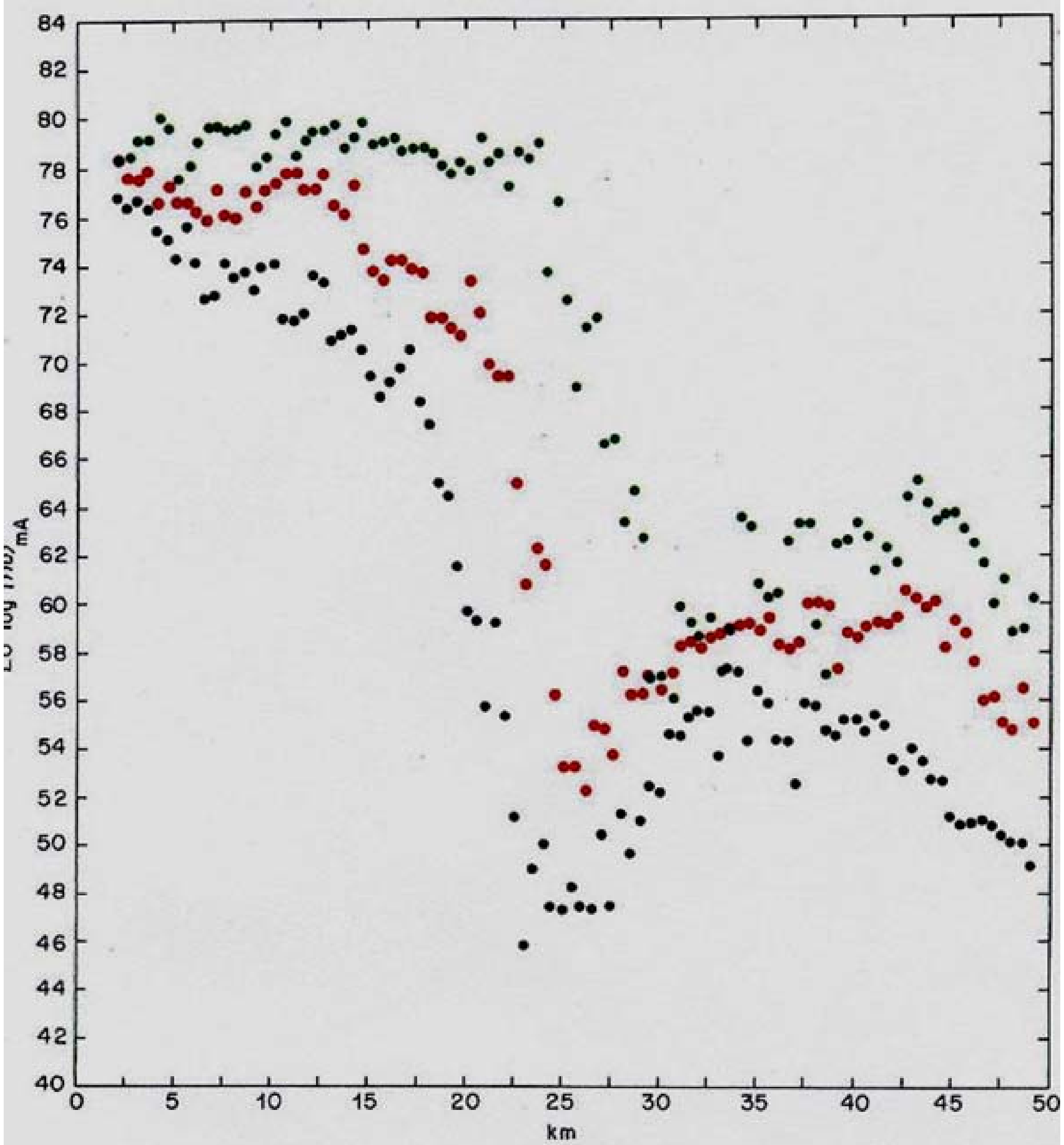
Does not indicate the transition from this regime and frequency range to adjacent situations

Surface waves in cities

In MF planning account has to be taken of the effective ground conductivity.

This works well in rural areas and also works in moderate size towns by assuming mixed paths with lower conductivity in the towns.

But does not work in cities. No assumptions for effective conductivity using the mixed path method can be made to fit.



Road measurements made along the radial 181° E.G.N. (three frequencies)

● 908 kHz ● 1214 kHz ● 1457 kHz

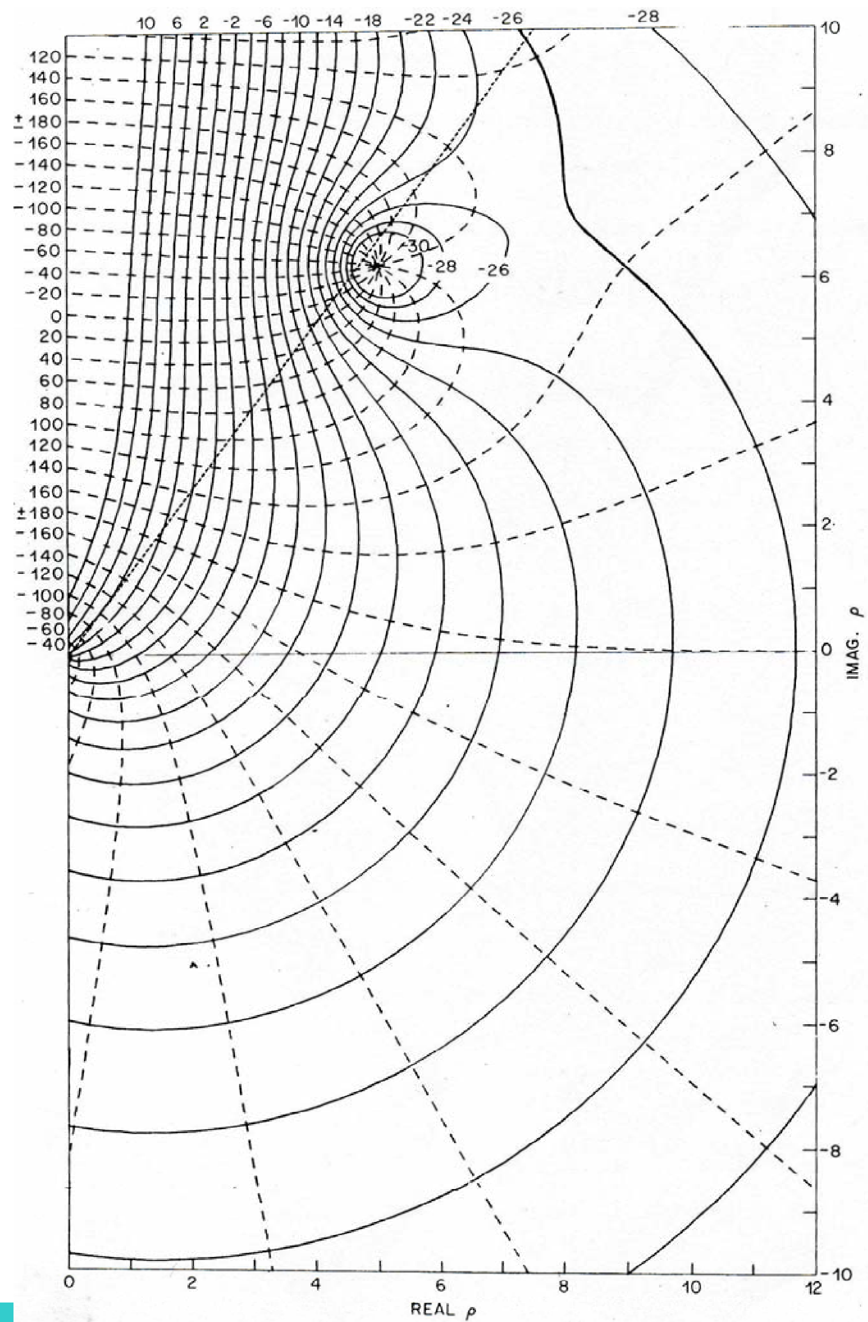
$$A = 1 - j\sqrt{\pi\rho}\cdot\exp(-\rho)erfc\left(j\sqrt{\rho}\right)$$

where

$$\rho = -j\pi\eta^2 r/\lambda$$

and the relative surface impedance, η, is:

$$\eta = \frac{\left(\varepsilon - j60\sigma\lambda - 1\right)^{1/2}}{\varepsilon - j60\sigma\lambda}$$



Causebrooke derived an empirical fit to his results in terms of:

- the height of the man-made structures,
- the fraction of the area covered with buildings
- the surface impedance of the underlying ground.

This gives the basis of a method for predicting the field strength in cities.

- more work needed to establish a procedure for paths which are partly in open country & partly in built up areas, and where building heights vary.

One further aspect needs more study.

Most domestic MF broadcast receivers use magnetic antennas, as do the usual field strength measuring instruments, but car antennas are generally electric.

Experience has shown that the magnetic field is more stable than the electric field in obstructed situations, and the ground wave environment is clearly one where the wave impedance differs from that in free space.

Conventionally, field strength measurements and predictions are in terms of the electric field. This needs to considered further.