

REPORT 1063

**PREDICTION AND CONTROL OF RE-RADIATION
IN MF BROADCASTING**

(Question 44/10, Study Programme 44G/10)

(1986)

1. Introduction**1.1 Re-radiation**

When the radiated field from a broadcast transmitting installation intercepts a metallic structure, currents are induced in that structure and it radiates a second field which adds vectorially to the original. This is known as re-radiation.

1.2 Re-radiating structures

Sound broadcasting at MF normally involves vertical radiators, usually insulated at the base, over an extensive conductive earth screen composed of many radial wires. Vertical metallic structures of appreciable height (about 15% or more of a wavelength) in the vicinity of such transmitting antennas may cause re-radiation problems. Typical structures include masts, towers, tall chimneys or heavy industry complexes. High-rise buildings may also be troublesome sources. However, the most common re-radiation hazard is high tension power transmission lines which use steel towers. It is normal on such lines to attach one or two "sky wires" to each tower, running parallel to and above the power conductors, so as to afford protection from lightning and to disperse any destructive currents present from either a lightning stroke or a fault involving the power conductors. The towers and sky wires, together with their images in the earth, form loops which tend to be one-wavelength resonant somewhere in the lower part of the MF band and two-wavelength resonant in the upper part. The power conductors themselves have little effect on the re-radiation.

1.3 Survey results

In Canada, about three-quarters of MF stations employ directional arrays.

A survey conducted in 1976 indicated that 28% of the respondents had suffered re-radiation problems and a further 25% were anticipating them. Steel-tower power lines were the chief offenders, with masts, tall buildings, smoke stacks and industrial complexes also mentioned. Costs of correction had varied from \$1000 to \$500 000 and in three instances the transmitter site had to be abandoned. One station anticipating problems for a new critical array required measures which involved the following: broadcast consultant — 5 days; station staff — 30 days; power utility engineers — 6 days; and riggers and linemen — 40 days [DOC, 1985].

2. Prediction methods

The extent of the re-radiation problem can be predicted by analytical methods, by scale-model tests or by full-scale measurements.

2.1 Analytical methods

An accurate method and one found to correlate reasonably well with scale model and full-scale tests, is the numerical electromagnetics code (NEC), developed at the Lawrence Livermore Laboratories in 1979 [Burke *et al.*, 1979].

It is a moment-method analysis, wherein all significant current conductors are broken into segments of 0.1 wavelength or less and represented by single wires of appropriate diameter or by plates of appropriate dimension. The program continues to adjust currents and phases between predetermined boundaries in each of these segments until the laws of electromagnetics are satisfied. NEC is a powerful tool, but has the disadvantage that it requires a major computer and is expensive in the time required for the run and for its analysis.

Another moment-method approach is provided by the Richmond program [Richmond, 1974a and b]. However, the NEC appears to be more versatile and has been used to analyse towers, buildings and power lines.

By use of transmission line theory, much less complex computer programs for analysis of power lines can be developed. One program by an electric power utility — Ontario Hydro — shows pattern distortions similar to those from the moment-methods but with re-radiation at resonant peaks lower by a factor of about 1.8. Another

program, simple enough to be run on a mini-computer and known as AMPL is recommended for initial analysis of power lines in the Canadian report [DOC, 1985]. The program is listed in that report. Agreement with the moment-methods is good up to 1100 kHz but less so, at the top of the MF band.

2.2 Scale model tests

Modelling of a transmitting antenna and of re-radiating objects usually at scales of 200 or 600 to one, has been done using radio ranges and an anechoic chamber in Canada. On the radio range, the models are placed on a conductive surface turntable and measurements are made at the edge of the conductive surface screen. In the anechoic chamber, no earth screen is used and models are made double their normal height so as to include their images in the earth.

2.3 Full-scale tests

Tests in the field have included numerous "before and after" tests on new power lines wherein the broadcast radiation pattern was measured with particular care ahead of and after construction of the power line and again after appropriate de-tuning procedures had been completed. Other tests involved the temporary installation of a low-power transmitter near isolated buildings or isolated test sections of power transmission lines. Details are included in the Canadian report [DOC, 1985].

3. Assessment procedures

Where construction of either a new broadcasting transmitter or a new re-radiation hazard is anticipated, a preliminary assessment of the potential effects is suggested, followed by the corrective action indicated in the circumstances.

3.1 Power transmission lines

Preliminary assessment using the program AMPL would give an indication of the seriousness of the problem. This could then be followed, if required, by an NEC analysis and appropriate procedures could be suggested. One Canadian station which had a fairly critical directional pattern, was faced with the construction of two nearby power lines. Computer projections by the moment-method indicated in which power line towers high re-radiating currents would flow and that re-radiation would indeed be excessive. The lines were built, and intolerable re-radiation was confirmed in field measurements. The most severely offending towers then had their sky wires isolated and the re-radiation dropped to acceptable levels.

3.2 Masts and towers

Using moment-method computation, the Communications Research Centre developed graphs of "scattering cross-section" (σ/λ^2) for a representative set of masts or towers which permit rapid assessment of the amplitude, though not the phase, of the re-radiation component in a field [Royer, 1985] (see Fig. 1).

At point, p , at distance, d :

$$|E| = |E_p| \pm |E_s|$$

where:

E_s : scattered field, and

E_p : normal field.

E_s can be determined, having obtained σ/λ^2 from the curve and knowing the incident field at the scatterer, E_{s0} , from:

$$\sigma = 4\pi d_p^2 \left| \frac{E_s}{E_{s0}} \right|$$

$|E|$ can be determined for any horizontal or vertical angle using moment-method analysis. Royer provides an extensive family of curves for this purpose. If the field value is of concern, appropriate action can be initiated.

3.3 High-rise buildings

Royer's work at the Communications Research Centre (see § 3.2) also included predictions for a representative set of buildings, modelled as wire grids. An example is given in Fig. 2. Techniques similar to those in § 3.2 can be employed.



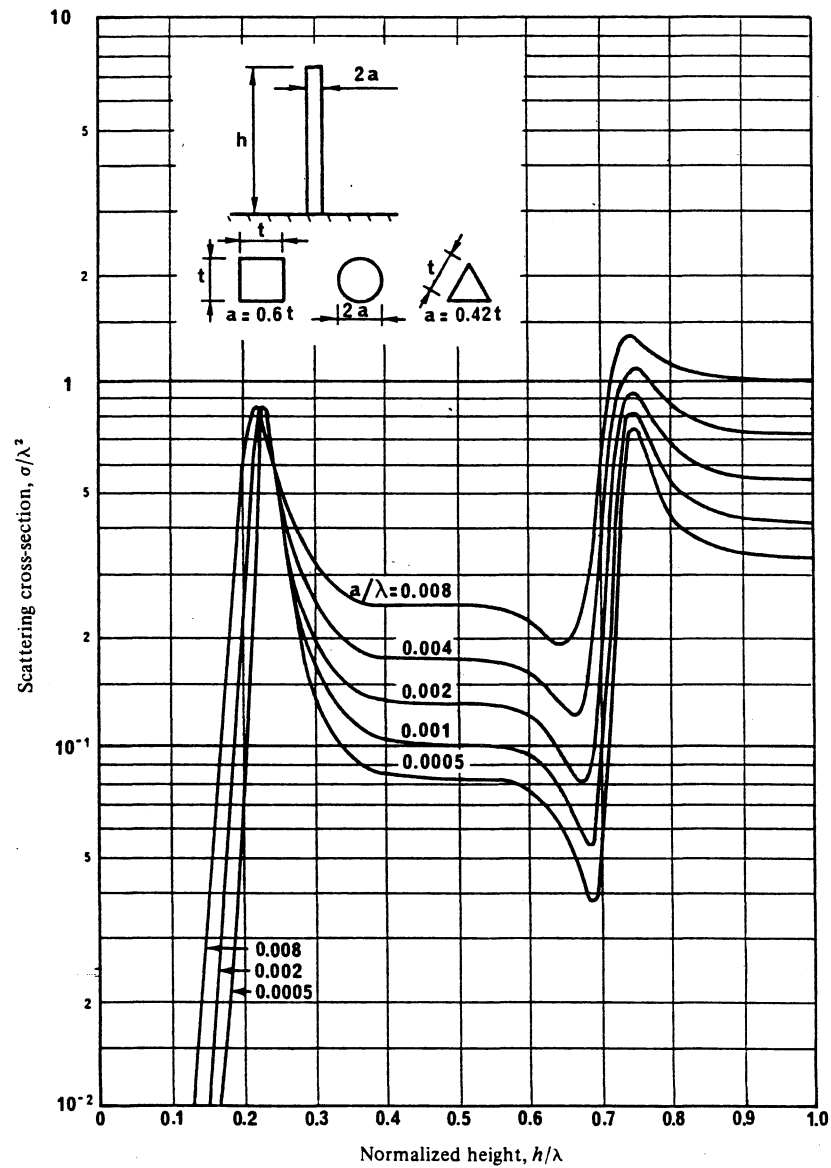


FIGURE 1 – Scattering cross-section for a representative set of masts and towers

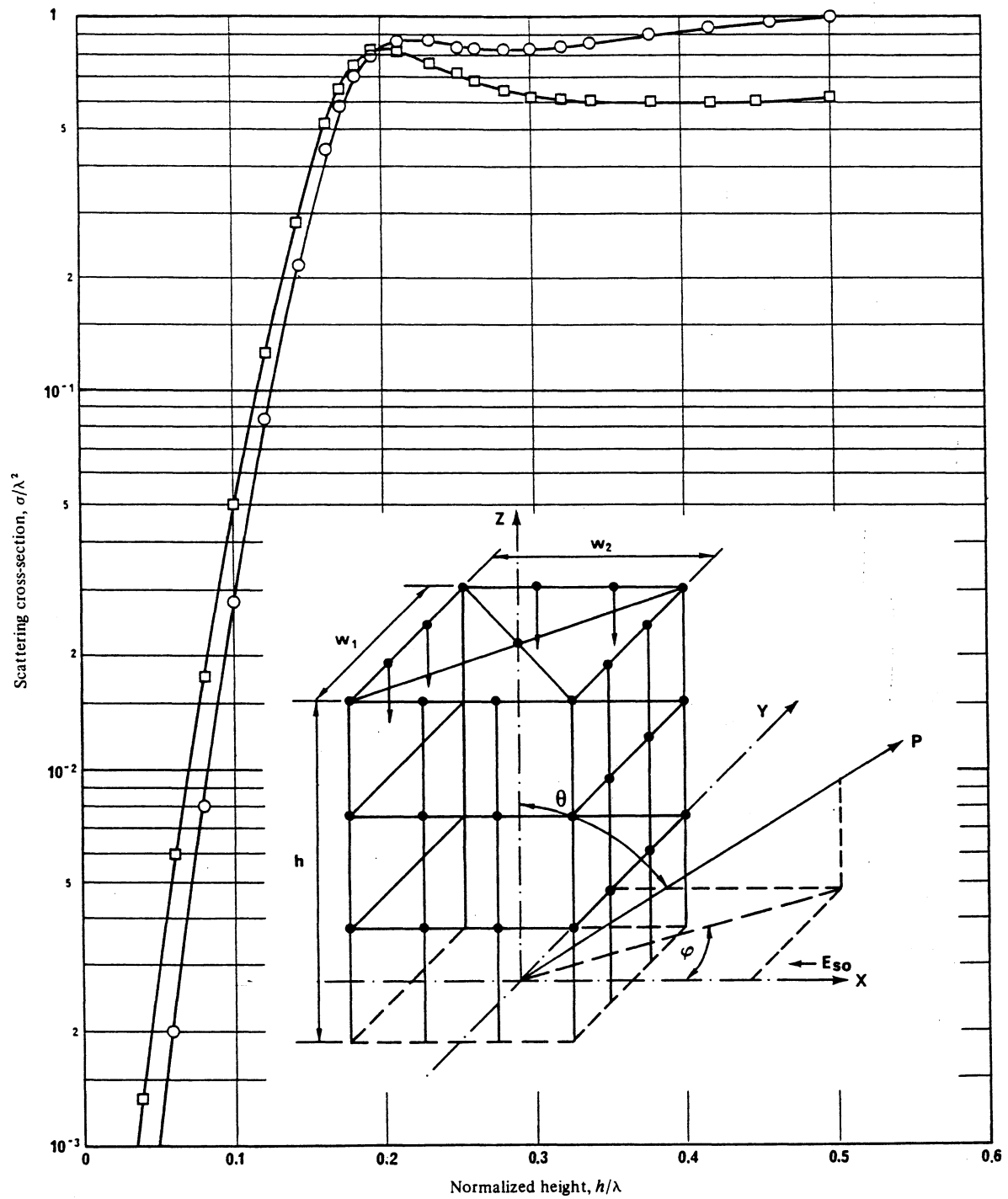


FIGURE 2 - Scattering cross-section for a representative set of buildings; modelled as wire grids

- : $\phi = 0^\circ$
- : $\phi = 180^\circ$
- $w_1 / \lambda = w_2 / \lambda = 0.200$
- a_0 (Wire radius) / $\lambda = 0.0016$

4. De-tuning techniques

4.1 *Isolation of sky wires*

Where power lines create a problem, a common technique is to install insulators between the towers and the sky wire, which is normally earthed at these points. This minimizes current flow in the adjacent loops. This method must be used judiciously, since it creates additional hazards in the case of lightning or fault-induced current flow and also may cause resonance at another frequency, affecting another station in the area.

4.2 *Stubs*

When a structure or loop is resonant, standing waves of current and voltage occur. Introducing an insulator at the point of maximum current flow would be the most effective cure but in most instances, this is impractical. An open quarter-wave stub can introduce high impedance at the point and is normally used for this purpose. Unfortunately, on power lines, maximum current on the sky wire usually occurs some distance out from the tower. A stub or insulator inserted at that point is very effective but finds little favour with power authorities who want no extraneous installations mounted above the power conductors. Stubs are also difficult to install or adjust in this location. Normal practice therefore has been to connect stubs to the tower legs just below the power conductors, suspending them about 1 m out, parallel to the legs and terminating them on the tower leg some 5 m above ground via a tuned reactance. Since the stubs are invariably less than one-quarter wavelength long, a variable capacitor is used. It is tuned to minimize current at the base of the tower leg.

An alternative tower stub has been developed, known as the "elbow stub" [DOC, 1985]. This starts at the tower just below the power conductors but is guyed out from the tower so as to form a right angle at mid-length, then return to the tower near the earth where the tuning components can be adjusted. Elbow stubs for two frequencies are found to be very effective when mounted on orthogonally opposed corners of the tower. Elbow stubs have also been proved to have a wider bandwidth than stubs parallel to the tower legs.

4.3 *Buildings*

Scale model and analytical predictions of re-radiation from buildings show reasonable agreement and are amenable to de-tuning techniques. However, the uncertain impedance of footings and the lossy nature of material such as concrete used in their construction cause somewhat anomalous results in de-tuning procedures at full scale.

De-tuning can be provided by stubs such as used on towers but the stubs are usually not acceptable aesthetically. An alternate stub arrangement can be provided by a roof-top stub supported 3 or 4 m above the building periphery, and connected through a suitable reactance to the lightning protection system. An improved roof-top stub is afforded by mounting an umbrella of a few wires above the roof, connecting their common point in a manner similar to the above.

In full-scale measurements in Canada, it was found that de-tuning, computed to provide about 18 dB reduction, resulted in only about 4 or 5 dB improvement. As explained above, this is attributed to the lossy nature of the structure. Further investigation is warranted.

REFERENCES

- BURKE, G. J., POGGIO, A. J., LOGAN, J. C. and ROCKWAY, J. W. [June, 1979] NEC-numerical electromagnetics code for antennas and scattering. Proc. IEEE International Symposium on Antennas and Propagation, Seattle, WA, USA, Vol. 1, 147-150.
- DOC [1985] Final Report of the working group on re-radiation problems in AM broadcasting. Dept. of Communications DOC, Ottawa, Ontario, Canada.
- RICHMOND, J. H. [May, 1974a] Radiation and scattering by thin-wire structures in the complex frequency domain. NASA Contractor Report CR-2396. NASA, Washington, DC, USA.
- RICHMOND, J. H. [June, 1974b] Computer program for thin-wire structures in a homogeneous conducting medium. NASA Contractor Report CR-2399. NASA, Washington, DC, USA.
- ROYER, G. M. [March, 1985] The distortion of AM broadcast antenna patterns as caused by nearby towers and high-rise buildings. CRC Report No. 1379. Communications Research Centre, Dept. of Communications, Ottawa, Ontario, Canada.

BIBLIOGRAPHY

- ALFORD, A. [December, 1977] Re-radiation from tall guyed towers located in a strong field of a directional AM radio station. *IEEE Trans. Broadcasting*, Vol. BC-23, 4, 97-106.
- KAVANAGH, S. J. and BALMAIN, K. G. [March, 1984] Highrise building re-radiation and de-tuning at MF. *IEEE Trans. Broadcasting*, Vol. BC-30, 1, 8-16.
- SAWADA, Y. and NAKAMURA, H. [1963] Development of a new wave trap by parallel sub-conductors. *Electron. and Telecomm. in Japan*, Vol. 8, 1/2, 70-77.
- SILVA, M. M., BALMAIN, K. G. and FORD, E. T. [September, 1982] Effects of power line re-radiation on the patterns of a dual-frequency MF antenna. *IEEE Trans. Broadcasting*, Vol. BC-28, 3, 94-103.
- TILSTON, M. A. and BALMAIN, K. G. [September, 1983] Medium frequency re-radiation from an unstrung steel power line tower. *IEEE Trans. Broadcasting*, Vol. BC-29, 3, 93-100.
- TILSTON, M. A. and BALMAIN, K. G. [March, 1984a] Medium frequency re-radiation from a steel tower power line with and without a de-tuner. *IEEE Trans. Broadcasting*, Vol. BC-30, 1, 17-26.
- TILSTON, M. A. and BALMAIN, K. G. [June, 1984b] A microcomputer program for predicting AM broadcast re-radiation from steel tower power lines. *IEEE Trans. Broadcasting*, Vol. BC-30, 2, 50-56.
- TRUEMAN, C. W. and KUBINA, S. J. [June, 1981] Numerical computation of the re-radiation from power lines at MF frequencies. *IEEE Trans. Broadcasting*, Vol. BC-27, 2, 39-45.
- TRUEMAN, C. W., KUBINA, S. J. and BELROSE, J. S. [August, 1983] Corrective measures for minimizing the interaction of power lines with MF broadcast antennas. *IEEE Trans. Electromag. Compt.*, Vol. EMC-25, 3, 329-338.
- TRUEMAN, C. W., KUBINA, S. J., MADGE, R. C. and JONES, D. E. [September, 1984] Comparison of computed RF current flow on a power line with full scale measurements. *IEEE Trans. Broadcasting*, Vol. BC-30, 3, 97-107.
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