EMC 80

INTERNATIONAL WROCŁAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Ground-wave propagation
Land mobile service
Transmission loss

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A NOVEL FORMULA FOR VHF/UHF PROPAGATION LOSS FOR LAND MOBILE COMMUNICATION IN RURAL TERRAIN

The simplified analysis of ground-wave propagation /called "unified analysis"/ in the 2 - 200 MHz frequency band was outlined by Prof. Wojnar and this author at the Third and Fourth Wrocław Symposia. The basic transmission loss /evaluated over the smooth, spherical earth within the adequate distance range/ changes proportionally to the distance raised to the fourth power. Multiple experiments have shown that this fourth-power-law is valid for frequencies up to approximately 500 ÷ 1000 MHz. It is, however, necessary to introduce corrections allowing for sphericity of earth and for dissipation due to terrain irregularity.

1. A novel approach

Approximate methods published so far assessed the scattering due to terrain morphology by introducing additional loss factors, proportional to frequency-squared /i.e. Egli I1I, Saxton I2I and AFAM-suburban [3] models/. Besides, more complicated computer methods were submitted. These methods /viz. CCIR A,B I4I and Durkin I5I methods/ account for many various propagation parameters. The complexity of computer methods restricts their use to precise engineering calculations.

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Rapid assessment of propagation loss /in a single radio link/ cannot be obtained this way. In order to approach a simple solution, let us return to the formulas originating from the unified analysis I6,7,8I. Assume that the ground-wave propagation mode exists /in pure form/ if I9I

$$h_{t,r} \leqslant 30\,\lambda^{2/3} \qquad /1/$$

where

$h_{t,r}$ - actual height of the transmitting/receiving antenna [m]

λ - the wavelength [m]

The ground-wave path between antennas exhibits basic /median/ transmission loss I7I equal to /in practical units/:

$$L_b = 120 + 40 \log d - 20 \log h_1 h_2 \quad [dB] \qquad /2/$$

where

d - the distance between antennas [km]

$h_{1,2} = \sqrt{h_{t,r}^2 + h_m^2}$,- the corrected elevation of the transmitting/receiving antenna [m]

and h_m - the apparent elevation of antennas [m]; see I6,8,10I.

Morphology and the curvature of the earth are responsible the additional transmission loss. If the frequency is raised the effects of irregularities in the terrain and the sphericity of earth are relatively more and more pronounced. The basic transmission loss L_b should then be supplemented by two correction factors ΔL_e and ΔL_p, so that first order estimate of the total loss L is given by

$$L = L_b + \Delta L_e + \Delta L_p \qquad /3/$$

where

$\Delta L_e/f,d/$ - additional loss factor accounting for the curvature of the earth

$\Delta L_p/f/$ - additional loss factor accounting for terrain morphology

Specifically, two novel expressions are here proposed to evaluate the correction factors:

$$\Delta L_e = 2{,}1 \cdot 10^{-3} \cdot d^{3/2} \cdot f^{1/2} \quad [dB] \qquad /4/$$

$$\Delta L_p = 10 \log f - 20 \quad [dB] \qquad /5/$$

where d [km], f [MHz].

The range of validity for /3/ may be assessed as

$$d_{min} \leqslant d \leqslant d_{max} = 45\,\lambda_{[m]}^{1/3} \quad [km] \qquad /6/$$

where d_{min} is lower limit of the basic zone in ground-wave propagation, see I10I.

Expression /4/ is not restricted as far as the frequency range is concerned. The analysis of experimental data permits us to contend that essential increment of transmission loss /accounting for real morphology of rural and suburban terrain/ above 100 MHz has been observed. Practically, in land mobile radiocommunication for the majority of type mobile-to-mobile and base-to-mobile radio links utilizing the frequencies below 100 MHz and low antennas, the additional loss factor may be omitted. In the range between 100 - 600 MHz it is necessary to use both correction factors.

It was tacitly assumed that the difference between 10% and 90% terrain contours over propagation paths does not exceed the value of terrain irregularity Δh = 15m /typical rural or suburban area/.

2. Validation of the novel method

The novel method of evaluating the additional transmission loss is in Fig. 1 compared to the simple Egli and Saxton methods therein, following values were substituted:

after Egli I1I

for $f \geq 40$ MHz $\quad \Delta L_p = 20 \log f_{[MHz]} - 32$ [dB]

for $f < 40$ MHz $\quad \Delta L_p = 0$

and after Saxton I2I

for $f \geq 70$ MHz $\quad \Delta L_p = 20 \log f_{[MHz]} - 37$ [dB]

for $f < 70$ MHz $\quad \Delta L_p = 0$

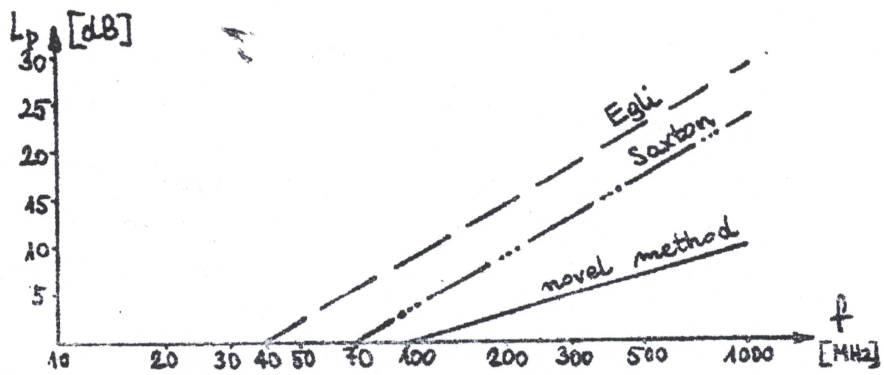

Fig. 1. The different estimates of the additional transmission loss caused by average terrain irregularities.

Let us that with this comparison the increase of transmission loss caused the curvature of earth is not taken into account in any of the methods.

Verification of the submitted method by experimental data and comparison to the propagation curves of CCIR I8I is shown in Fig. 2. It follows that the assessment of transmission loss by expression /3/ can be regarded as satisfactory in technical sense.

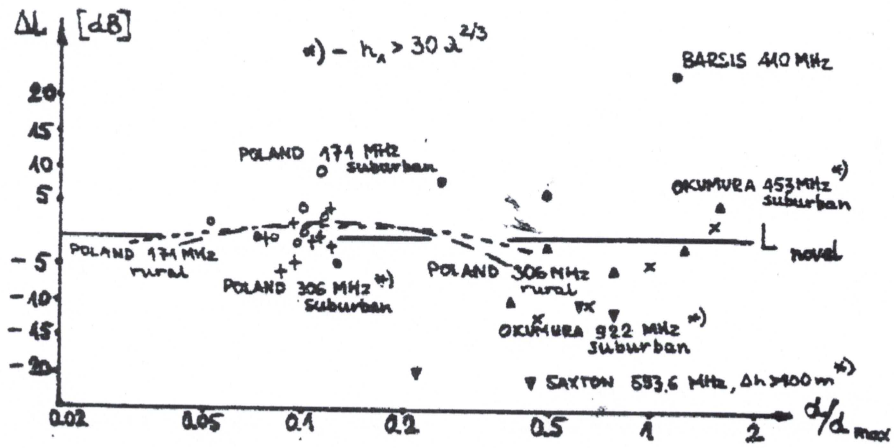

Fig.2. Median transmission loss evaluated by the novel method as compared to experimental data.

The use of Egli or Saxton method for calculations results in "too pessimistic" estimates of transmission loss. This leads to overdimensioning of the radiated power of transmitters, with increased pollution of the EM environment as a result.

3. Conclusions

Novel formulas facilitate rapid calculations of the transmission loss in the ground-wave propagation /beyond-horizon scattering disregarded/ over rural and suburban area. The formulas are valid in the frequency range from ca 100 MHz to ca 600MHz /probably the upper limit can be extended to ca 1000 MHz/ with average terrain irregularities. The presented verification of the submitted formulas shows that the accuracy of the assessment /in the limited range of the frequency, distance and antenna heights/ seems satisfactory for the engineering practice.

The novel approach is recommended for approximate calculations of the median transmission loss in typical individual mobile radio links so that more complicated and costly computer methods can be replaced by simple calculator-assisted operations.

4. Acknowledgment

This author wish to acknowledge the aid and encouragement from Prof. Dr. Wojnar, especially during the preparation of the paper.

5. References

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НОВАЯ ФОРМУЛА ОЦЕНКИ ПОТЕРЬ ЭНЕРГИИ ПРИ РАСПРОСТРАНЕНИИ РАДИОВОЛН НА ТРАССЕ НАЗЕМНОЙ ПОДВИЖНОЙ РАДИОСВЯЗИ В СЕЛЬСКОЙ МЕСТНОСТИ.

Основные потери энергии на радиотрассе при распространении электромагнитных волн в диапазоне 2 - 200 МГц обозначены кратко представленым на Третьем и Четвертом Вроцлавском Симпозиуме методом упрощенного анализа пропорционально зависят от четвертой степени междуантенного расстояния (в области радиогоризонта над сферической поверхностью Земли).

Как известно, этот закон имеет силу также в диапазоне до 1000 МГц, но надо внести дополнительные поправки на рассеивание волн от неровной поверхности а также на учёт кривизны Земли. Предложенный метод делает возможной быструю оценку медианы потерь энергии на радиотрассе в сельской местности о несколько шероховатой поверхности (при распространении радиоволн в области радиогоризонта для диапазона частот 100 ÷ 600 МГц).

В докладе представлены также сравнения предвиденных величин медианы потерь энергии на разных радиотрассах, полученных этим методом (а также другими, известными по литературе методами), с множеством экспериментальных данных.

Рис.1. Различные методы оценки дополнительной потери энергии на радиотрассе о несколько шероховатой поверхности.

Рис.2. Сравнение оценки величины медианы потерь энергии с экспериментальными данными.