ESTIMATION OF ELECTRICAL CONSTANTS OF FOREST SLAB BY INVERSE METHOD

R.K.TEWARI, S.SWARUP, Member IEEE
DEFENCE ELECTRONICS APPLICATIONS LAB, DEHRA DUN, INDIA
M.N.ROY, Senior Member IEEE
JADAVPUR UNIVERSITY, CALCUTTA, INDIA

ABSTRACT: Inverse method has been used to determine the relative permittivity(ϵ_r) and the conductivity (σ) of the forest slab in which radiowave propagation data has been collected. The range of ϵ_r and σ values thus obtained are found to be in good agreement with those reported in literature. The experimentally measured values of these constants have been reported only upto 75 MHz whereas the present study covered the frequency range upto 800 MHz and hence it is significant.

INTRODUCTION: The forest could be distinguished by their physical as well as electromagnetic properties. The physical properties are the height and diameter distribution of the trees in a given forest area, their mutual spacings, undergrowth and the climatic conditions. The basic e.m. properties which determine the radiowave propagation characteristics of any media are its relative permittivity(ϵ_r)and conductivity (σ). The forest media is considered to be locally homogenous on a macroscopic scale and the values of ϵ_r and σ are thought to be the mean effective values in such a medium which is a mixture of irregularly distributed vegetation and air. Various theoretical as well as experimental techniques for evaluating ϵ_r and σ have been reported. Open wire transmission line (OWL) probes [1,2] , parallel plate capacitor and cavity techniques [2] were used for direct and insitu measurements of the vegetation constants. The parallel plate technique was found to have many limitations whereas the cavity technique was not found suitable for measurements even at HF and VHF ranges. The OWL technique, though successfully used, was restricted to the frequency of 75 MHz. The experimental data collected from the measurements of antenna patterns in vegetation [3], reflection coefficient[4], attenuation constant[5,6,7]and transmission loss [8,9] have been used for estimation of $\epsilon_r$and σ by inverse methods for frequencies upto 400 MHz. These investigations resulted into large range of values of ϵ_r and σ. The major limitations of fitting the experimental data into the respective theoretical models containing ϵ_r and σ and making the quantitative estimation of the vegetation constants, had been that the parameters thus obtained were not uniquely defined. With this in view, in the present study, two such sets of propagation data viz. through-the-foliage attenuation constant (Δ f) and lateral were attenuation constant(α_L) were used to compute a unique set of values for ϵ_r and σ by inverse method.

RATE OF ATTENUATION,THROUGH-THE-FOLIAGE(Δ f): At very snort communication ranges, an foliated terrain, the predominant mode of propagation of radiowaves is through the forest slab and the received field has an additional attenuation factor [10] over and above the loss suffered in the absence of foliage. This factor is given by

$$\mathrm{Exp}(-2\pi/\lambda)\, d \sqrt{\epsilon_r'} \qquad (1)$$

where λ is the wavelength of transmission, d is the thickness of the forest slab through which the radiowaves propagate and ϵ_r' is the complex relative permittivity of the forest slab. The rate of foliage attenuation (dB/m) would then be

$$\Delta f = (2\pi/\lambda)\, \mathrm{Im}.\sqrt{\epsilon_r'} \qquad (2)$$

or

$$\Delta f = (2\pi/\lambda)\, \mathrm{Im}.\sqrt{\epsilon_r - j\sigma/\omega\epsilon_0} \qquad (3)$$

where ϵ_0 is the absolute permittivity of air(8.84×10^{-12} fared/meter).

LATERAL WAVE ATTENUATION CONSTANT(Δf): Beyond a nominal distance of about 0.4 Km, the received field in foliated terrain is characterised by lateral waves, the magnitude of which is given by[8]

$$E_L = \frac{60 I.l}{|\epsilon_r' - 1|} \; \frac{e^{-\alpha_L (2h - z - z_0)}}{d^2} \qquad (4)$$

where I.l is the fixed current moment, h is the average height of the forest, z,& z_0 are the heights of the receiving and transmitting antennas respectively, and

$$\alpha_L = \frac{2\pi}{\lambda}\; \mathrm{Im}.\sqrt{\epsilon_r' - 1} \qquad (5)$$

or

$$\alpha_L = \frac{2\pi}{\lambda}\; \mathrm{Im}.\sqrt{(\epsilon_r - 1) - j\frac{\sigma}{\omega\epsilon_0}} \qquad (6)$$

RESULTS AND DISCUSSIONS: The experimental data on Δf and α_L was obtained through the measurements conducted by authors [11,12]. The Δf was obtained by measurements at distances ranging from 40 m to 400 m to ensure the dominance of through-the-foliage mode of propagation. The height gain data collected for near the tree-top heights, for large separation distances between transmitter and receiver ($>$ 1 Km), to ensure the predominance of lateral wave mode of propagation, was used for evaluation of α_L. By solving the two equations (3) and (6) for Δf and α_L, the unique set of values of the unknown variable, ϵ_r and σ, were determined. This method is unique in another sense that Δf takes care of the horizontal distribution of the forest and α_L caters for their vertical distribution. The ground effect has been considered to be negligible as the data pertains to large antenna heights.

The values of electrical constants, thus computed, as well as those obtained by others have been tabulated in Table 1. The results obtained in this study show consistently good agreement. However, comparison of these constants for frequencies above 400 MHz could not be made since the data at higher frequencies has not been reported.

Table 1: Electrical Constants for Forest

Measurement Sites	Source	Frequency Range (MHz)	ϵ_r	σ (mho/m)
Present Study (India)	Tewari[13]	200	1.010	0.064
		500	1.013	0.092
		800	1.020	0.119
Pak Chong (Thailand)	Sachs[8]	6-100	1.02	0.125
	Hicks[9]	2-400	1.01	0.045
	OWL [1,2]	6-75	1.02	0.02-1.13
Satun (Thailand)	Hicks [9]	2-400	1.01	0.035
	OWL [1,2]	6-75	1.01	0.01-0.1

ACKNOWLEDGEMENTS: The authors wish to thank Messers N.S.Chhabra, M.L.Agrawal, K.Siva Kumar, Hazara Singh, M.Sazid and G.C.Pandey for helping in the field measurements and to Mr.C.P.Sharma,Director DEAL for his continuous encouragement and permission to publish this paper.

REFERENCES

1. H.W.Parker and W.Makarabhiromya, "Electric constants measured in vegetation and in earth at five sites in Thailand", Stanford Research Institute, Menlo Park, Calif., Special Tech. Rept. No.43, Dec.1967.

2. H.W.Parker and G.H.Hagn,"Feasibility study of the use of open wire transmission lines, capacitors and cavities to measure the electrical properties of vegetation", Stanford Research Institute, Menlo Park, Calif., Special Tech. Rept. No.13, Aug.1966.

3. G.E.Barker, J.Taylor and G.H.Hagn,"Summary of measurements and modelling of the radiation patterns of simple HF field antenna in open (level) terrain, mountains and forests" Stanford Research Institute,Calif., Special Tech. Rept. No.45, Dec.1971.

4. N.K.Shrauger and E.M.Kreinberg,"Selected examples of VHF signal propagation records in tropical terrains", Stanford Research Institute, Calif., Special Tech.Rept., No.36,Nov.1967.

5. T.Tamir, "On radiowave propagation in forest environments" IEEE Trans. Ant. & Prop.Vol.AP-15, No.6, PP 806-817,Nov.1967.

6. G.E.Barker, "Measurements of the radiation patterns of full scale HF and VHF antennas", IEEE Trans. Ant. & Prop., Vol.Ap-21, No.4,pp 538-544, July 1973.

7. G.H.Hagn, N.K.Shrauger and R.S.Shepherd,"VHF propagation results using low antenna heights in tropical forests".Stanford Research Institute,Calif.,Special Tecn.Rept.No.46,March 1973.

8. D.L.Sache and P.J. Wyatt,"A conducting slab model for e.m. propagation within a jungle medium", Radio Science, Vol.3(New series), No.2, pp 125-134, Feb.1968.

9. Tropical propagation Research, Final Report, Vol.II, Jansky and Bailey Division, Atlantic Research Corpn.Alexandria,Virginia, USA, 1969.

10. Recommendations and Reports of the CCIR XIV Plenary Assembly, Kyoto, Vol.V, Propagation in Non-ionised media, Rept.No.236-4, pp 54-55, 1978.

11. S.Swarup and R.K.Tewari, "Depolarisation of radiowaves in Jungle environment", IEEE Trans. Ant. and Prop., Vol.AP-27, No.1, pp 113-116, Jan.1979.

12. R.K.Tewari, S.Swarup and M.N.Roy, "Height gain in forest medium: an empirical analysis" Symposium Digest,1982 International IEEE/AP-S Symposium and National Radio Science Meeting, New Mexico(USA), Vol.1, pp 332-335, May 1982.

13. R.K.Tewari, "Studies on the effects of vegetation on radiowave propagation in tropical rain forest of India,Ph.D.Thesis, 1982.