View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Engineering 15 (2011) 2206 – 2210
Procedia Engineering
www.elsevier.com/locate/procedia

Advanced in Control Engineeringand Information Science

Propagation path loss prediction model of multi-sensor network in forest

Yun-Jie Xu[a,b], Wen-Bin Li [a]*

[a] Beijing Forestry University, Beijing, 100083, China
[b] Zhejiang Agricultural & Forestry University, Lin'an, 311300, China

Abstract

During the process of carrying on the master plan and design of multi-sensor network in forest, We must consider the coverage of the signal, how to find the best position, through predicting it from launching and checking to accepting the loss value of the electromagnetic wave checked, Can carry on planning and design. Based on the radio wave propagation loss model in free space and the characteristics of radio wave propagation in forest, this paper proposes the generalized predicting model of radio wave propagation loss, To validate the model, a radio propagation measurement campaign was carried out, The modeling results by measuring the parameters of some trees are good agreement with that of the literature.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and/or peer-review under responsibility of [CEIS 2011]

Keywords: Propagation path loss; forest; prediction model; UHF

1. Introduction

Recently the technology of wireless sensor network is extensively applied in industry and agricultural production[1]. However, this technology is relatively less applied in forestry production. Moreover, there are many research on the propagation loss of radio wave, however the study about the propagation of high-frequency wave in forest is relatively less carried out. The complicated geographical environment makes the signal attenuate severely [2]. We have introduced the ZigBee technology of wireless sensor network into the survey of forestry resource information, and constructed the survey system of forestry resource information based on the ZigBee technology of wireless sensor network. When the power of this

* Corresponding author.
E-mail address:xyj9000@163.com; leewb@bjfu.edu.cn.

1877-7058 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2011.08.413

system is 100 mill watt, the communication distance is beyond 100 meters in clearing and 50 meters in the forest, which can realize the survey of many parameters such as forestry biomass, temperature and relative humidity etc and send them to the computer in the monitoring center. The sensor has a data acquisition multi-interface, which connects sensors of temperature, illumination and moisture of soil etc with diameter at breast height by measuring, and achieving wireless communication of organize meshwork between sensors. Our system could be used practically in the dynamic monitoring forest growing stock, and can obtain biomass ranges of the trees which grew in different directions. This information is useful during making policy to prevent or put out a fire in the forest [3].

However, we found that little or no signal is receive by sensors when they cling to the stem. This phenomenon is the diffraction of electromagnetic waves propagation. The diffraction appears when electromagnetic waves come across the obstacles with the edge of standing tree. The bigger frequency is, and the decreased capability of diffraction is. Diffraction ability of signal of 2.4GHz sensors is bad because of their anti-jamming of electromagnetic and stability. If we can accurately compute field, then the sensor can be installed correctly, and thus effective communication can be derived.

As a continued work from the previous one, the main objective of this paper is to study the generalized predicting model of radio wave propagation loss.

2. Model Analysis

Propagation mechanisms are very complex and diverse. First, because of the separation between the receiver and the transmitter, attenuation (reduction or loss) of the signal strength occurs. In addition, the signal propagates in different manners, known as diffraction, scattering, reflection, transmission, and refraction.

Estimating the signal attenuation caused by diffraction of radio waves forest is essential in predicting the field strength in a given service area. Generally, it is impossible to make very precise estimates of the diffraction losses, and in practice prediction is a process of theoretical approximation modified by necessary empirical corrections [4].

Fig.1. is a typical flow chart for a signal strength prediction method. As shown in the bottom, clutter loss, which is caused by objects such as trees, is an inevitable factor in radio wave propagation.

One of the major problems in predicting field strength in the point-to-point environment is the variation in losses due to forest.

3. Radio wave propagation loss modeling

Because the fields passing through the forest are highly attenuated, the dominant contribution to the signal received by a subscriber in the forest must come from fields that propagate via other paths that are predominantly in the air. To model the propagation Tamir representation the forest by a lossy dielectric layer with complex dielectric constant, with this representation, he was able to show that at long distances mobile-to-mobile propagation takes place via a lateral wave in the air propagating parallel to the forest canopy, as indicated. The lateral wave is excited by a ray reaching the treetops from the transmitter at the critical angle θ, and it radiates back into the forest at the critical angle[5].

At UHF(200MHz-2000MHz). Tamir's model no longer holds because only the absorption of the forests is considered and the scattering behavior of the scatterers (tree trunks, leaves and branches) is ignored. Therefore, it is necessary to set up a forest model suitable for UHF and then to calculate the radio losses at UHF and clarify which wave is the dominant wave at UHF.

To this end, the forest has to be considered as a discrete random medium represent able as a time-invariant ensemble of randomly positioned and oriented canonical scatterers. The electromagnetic wave propagating in this medium may be represented as the sum of three components: Propagation loss in free space model *L (f)*, Propagation loss of diffraction *L (d)* and Propagation loss in forest *L (dB)*.

Tree trunks are replaced by absorbing screens. The leaves and branches are replaced by partially attenuating screens. For simplicity, the phase and attenuation screen is located directly above the absorbing screen. Propagation loss model is shown in Fig.2.

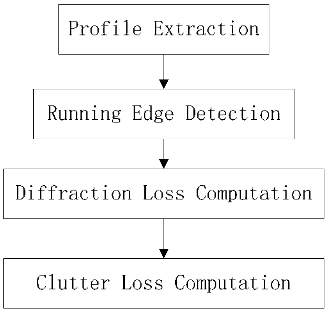


Fig.1. Signal Strength Prediction Procedure

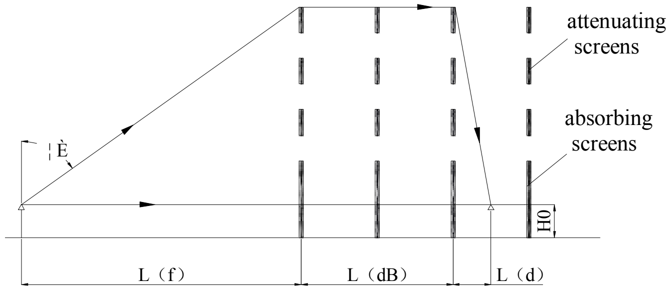


Fig.2. Radio propagation loss model

3.1. Signal strength calculated in free space model

In order to account for the distance effect when analyzing the vegetation type or blockage effects, the field signal strength needs to be compared to a function of distance from the transmitter. Because the path loss of signal strength in this project was measured in decibels, the path loss caused by distance could not be standardized by a simple division by distance; the procedure must be more in line with theory.

In this research Path Loss is computed by a common industrial approximation known as the Friis formula:

$$L(f) = 32.44 + 20\log(Dist. - km) + 20\log(Freq. - MHz) \tag{1}$$

In this project the test frequency was constantly 806MHz, hence signal strength in free space model for each sample point is simply a function of distance to the transmitter. It was easily calculated in an ArcMap attribute table column.

3.2. The diffraction loss model

Where the source is located at(x_0,y_0,z_0), and the receiving point is located at(x_1,y_1,z_1) after diffraction of stand tree. The radial can be divided into two components: one is that the incident energy propagates straightly according to the law of geometrical optics, and the other is that the incident energy propagates along the edge of stand tree, and the shadow and transition regions are formed when the radial of edge continual give off diffracted radial along the tangency. By accounting for application of the disposal of the sensor, we only consider the illuminated region and the shadow in this paper. Rugged stem's surface isn't an ideal conducting cylinder, so the diffraction fields the shadow of standing tree diffraction are solved by using polygons to approximately take the place of the circle. Where(x_0,y_0,z_0)is source point, (x',y',z') is the secondary source point, (x_1,y_1,z_1)and (x_n,y_n,z_n)is the receiver point with the number border of polygon n.

In shadow regions the diffracted field provides the only contribution to the total field, and the path gain PG. with the help of expression for the diffracted field, PG for isotropic antennas having is given by

$$PG = \left(\frac{\lambda}{4\pi}\right)^2 \frac{|D(\theta)|^2}{\cos^2\alpha'} \frac{1}{r_s r_R (r_s + r_R)} \tag{2}$$

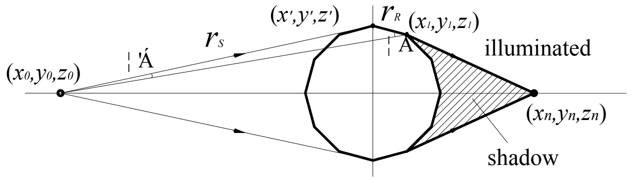


Fig.3. The diffraction model of stand tree

where *D(θ)*is the diffraction coefficient, *α'* is the incident angle, r_s is the distance from the source point to secondary source point *(x',y',z')*, r_R is the distance from the secondary source point in the plane *x*=0 to the receiver point (x_1,y_1,z_1), and the wavelength *λ*.

Recall that the path loss L in decibels is

$$L\ (d) = -10\log PG \tag{3}$$

3.3. Propagation loss modeling

At UHF, his principal mechanism responsible for long-distance propagation is the so-called lateral wave, which skims along the tree tops. Neglecting ground reflection, and for horizontal separations R that are large compared to the vertical dimensions, the path loss *L (dB)* is found to be

$$L(dB) = 10\log_{10}\left[\left|\frac{2I}{dlE_{2Z}}\right|^2\left(\frac{R(z')}{R_0}\right)\left(\frac{R(z')}{R_0}R_0^2\right)\right] \tag{4}$$

Is a good measure of the space attenuation of the radio wave where E_{2z}, can be the direct wave, reflected wave or lateral wave, respectively, with its propagation loss *L* in *dB*. *R(z')*and *R(z)* are the radiation resistances of the transmitting and the receiving dipoles respectively, at height *z'* and z with respect to the ground, and $R_0=80(\pi dl/\lambda_0)^2$.

is the radiation resistance of a small dipole in unbounded free space: $R(z')/R_0$ and $R(z)/ R_0$ in the Eq. (4) are taken from Vogler and Noble.

To this end, the electromagnetic wave propagating be represented as the sum of three components:

$$L = L(f) + L(d) + L(dB) \tag{5}$$

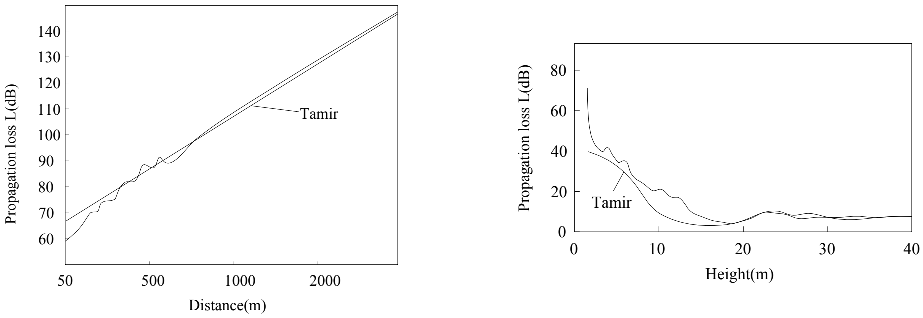
This UHF forest model includes not only both the scattering and the absorption behaviors of the forests but also the effects of the ground and the difference between the tree trunks and the foliage. This model is then used to evaluate the radio losses of the directed wave, reflected wave and lateral wave in forests by the parameters obtained by Lang, and to show that the lateral wave is still the dominant wave at UHF.

4. Model Simulation Result and Analysis

We take the birch as example, the frequency of source point in the base station *f*=2.4GHz, source and receiver are equal height, namely diameter at breast height *z*=1.3m. The field distribution of the birch measured loss by the Protek3290N strength apparatus.

Fig.4. shows that the propagation loss of the receiver power increasing with the increasing distance of source, i.e. the propagation loss adds because the free space propagation loss increases.

Fig.5. shows the measured attenuation for several frequencies, as a function of the receiver height, for the case of the receiver being placed in clear view of the transmitter. One can see that the measured signal varies dramatically with height. This is due to the interference between the direct ray from transmitter to receiver, and that reflected by the tree's height.



(a) distance (b) height

Fig.4. The variation between the propagation loss and the distance and the height

5. Conclusion

This work has presented a theoretical study to calculate propagation path loss field received a forest environment. The results involve relatively simple formulas, which can be interpreted in terms of ray paths. This model will be used to evaluate the propagation path loss in forests at UHF. This UHF forest model is more reasonable since it includes not only both the scattering and the absorption behaviors of the forests but also the effects of the ground and the difference between the tree trunks and the foliage. To validate the model, a radio propagation measurement campaign was carried out. The measured experimental results, obtained, demonstrate that this model can be used to prediction propagation path loss of multi-sensor network in forest. The results demonstrated that the proposed model presented the best performance comparing to Tamir's model in this work.

Acknowledgements

This work was supported in part by the National Natural Science Foundation of China (Grant No. 30972425). Corresponding author: Wen-Bin Li.

References

[1] Wang Qiu-ping，Li Hong-wei，Qi Zhao-jie. Research on Wireless Local Area Network Technology Applied In Precision Agricultural. Journal of Agricultural Mechanization Research, 2005,5: 209-211.

[2] LI Wen-bin; ZHANG Jun-mei; SA Chao; WANG De-ming ; GAO Kai. Model for forecasting the electric field intensity of UHF wireless frequency band in forests. Journal of Beijing Forestry University, 29(4):15-18, 2007.

[3] ZHANGJun-guo ; LI Wen-bin ; HAN Ning ; KAN Jiang2ming. Forest f ire detection system based on ZigBee wireless sensor network. Journal of Beijing Forestry University, 29(4):41-45, 2007.

[4] T. S. Rappaport, J. H. Reed, B. D. Woerner, IEEE Communications Magazine, 1996, 34(10): 33-41.

[5] Li Qing .GIS Aided Radio Wave Propagation Modeling and Analysis Master of Science In Geography of Virginia Polytechnic Institute and State University.2005.