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A Software Design Tool for Microwave Radio

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ABSTRACT

This paper deals with wave propagation calculation and cost optimization software development for microwave radio. The software presents a design tool for line of sight link planning. The main cost factor in a microwave network depends on tower structure and antenna heights. Antenna heights are normally chosen to overcome the first Fresnel zone obstruction. A software tool for the analysis and evaluation of a single microwave relay link has been developed. In addition, cost optimization method for a microwave radio network involving more than two antennas has been developed. This paper includes calculations and analysis of the geographical data in the chosen area in order to determine the effective earth's radius to achieve better optimization. In addition, terrain profile generation and microwave point-to-point link calculation was considered.

ABSTRAK

Kertas ini membincangkan pengiraan perambatan gelombang dan pembangunan perisian pengoptimuman kos bagi radio gelombang mikro. Perisian memaparkan suatu alat reka bentuk bagi perancangan pautan garis nampak. Kos utama suatu rangkaian gelombang mikro bergantung kepada struktur menara dan ketinggian antena. Biasanya, ketinggian antena dipilih supaya dapat melepasi halangan zon Fresnel yang pertama. Suatu perisian bagi menganalisis dan menilai pautan geganti gelombang mikro tunggal telah dibangunkan. Di samping itu, kaedah pengoptimuman kos bagi rangkaian radio gelombang mikro yang melibatkan lebih daripada dua antena telah juga dibangunkan. Kertas ini juga mengandungi pengiraan dan analisis data geografi bagi kawasan yang dipilih untuk menentukan jejari bumi berkesan supaya pengoptimuman yang lebih baik dihasilkan. Seterusnya, perjanaan profil rupa bumi dan pengiraan pautan gelombang mikro titik-ke-titik telah dipertimbangkan.

INTRODUCTION

Radio wave propagation is affected by many factors including the operating frequency, distance between transmitter (Tx) and receiver (Rx), antenna types, antenna height, curvature of the earth, atmospheric conditions, and the presence of obstacles, such as hills and buildings. Microwave radio operates in microwave frequency range. The distance between the transmitting antenna and the receiving antenna is in a range of few kilometers. The antenna used is the directional antenna. The method used is an extension of the single link algorithm (Ashraf & Faizal 1995a, 1995b, 1995c).

The microwave band provides the potential for more services than all of the lower radio bands together. Unfortunately, shorter wave lengths are more attenuated by absorption and scattering from rain, dust and sand particles in the radio path. If the excess attenuation exceeds the available fade margin the result is a service interruption and a system outage.

Meteorological elements are used to calculate the radio refractivity such as temperature, relative humidity and atmospheric pressure. The effective earth radius was calculated from the measured refractivity gradient N of the air at various altitudes above the earth's surface (CCIR 1982). The effective earth radius factor relates curvature of the ray path to the true earth radius. The distribution of mean values of N can be found in the CCIR Report (563) (CCIR 1982).

Radio transmission loss in tropospheric propagation depends on the characteristics of the atmosphere and the terrain. The most important atmospheric parameter is the refractive index gradient near the earth surface. This surface gradient largely determines the bending of a radio ray through the atmosphere.

The refraction index of air is close to unity. The radio refractivity, N, is defined as:

$$N = (n - 1) \times 10^6, \qquad (1)$$

where n is the index of refraction.

At radio frequencies, the radio refractivity may be approximated by:

$$N = 77.6\frac{AP}{T} + 3.73 \times 10^5 \frac{H}{T^2}, \qquad (2)$$

where AP is the atmospheric pressure (mbar), T absolute temperature (Kelvin) and H water vapour pressure (mbar).

The effective earth's radius, K, which is a function of the refractivity gradient or of the mean surface refractivity, N_s, is chosen to characterize average atmospheric conditions. The effective earth's radius for regional difference in average atmospheric conditions is defined as:

$$K = 6370\,[1 - 0.04665 \exp(0.005577\, N_s)]^{-1}. \qquad (3)$$

The actual radius of the earth was taken to be 6370 kilometers. The refractivity, N_s, represents the surface refractivity reduced to the sea level:

$$N_s = N_o \exp(-0.1057 h_s), \qquad (4)$$

where h_s is the elevation of the earth's surface in kilometer above the mean sea level and N_0 is the minimum monthly mean values of radio refractivity through the world.

The water vapor pressure is given in mm hg according to the temperature (Perry & Chilton 1973). This value is multiplied by a constant 1.33 in order to convert it to mbar. Those values are given at 100% relative humidity. In the calculation we consider the measured relative humidity by multiplying the value of the water vapor by the percentage of the relative humility at a certain time and place.

The presence of hills and buildings is taken into consideration in the design of the microwave link. The design of a diffraction loss and reliable microwave line of sight radio relay links presents a significant challenge to the designer. High cost of the antenna is one part of the technical problems encountered. Restrictions stemming from government regulations and national interests have further complicated the system designer task.

THE K-FACTOR VALUE IN THE AREA OF STUDY

The areas of study involve Bandar Baru Bangi and Kuala Lumpur. The meteorological data was collected from the UKM and Petaling Jaya meteorological stations. K-factor is defined as the ratio of the effective earth radius and real earth radius. Figure 1 shows the values of K-factor at Kuala Lumpur area in 1993. Figures 2 and 3 show the value of K-factor at Bandar Baru Bangi area in 1993 and 1994 respectively.

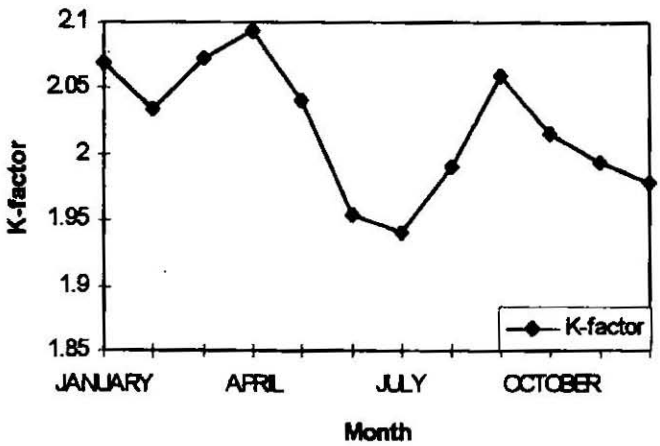

FIGURE 1. The K-factor at Kuala Lumpur in 1993

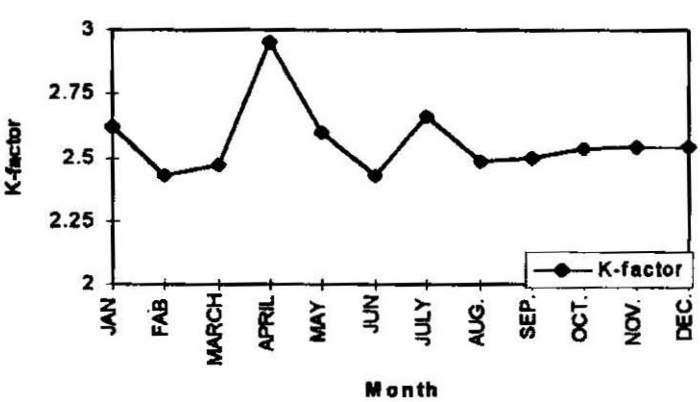

FIGURE 2. The K-factor at Bandar Baru Bangi in 1993

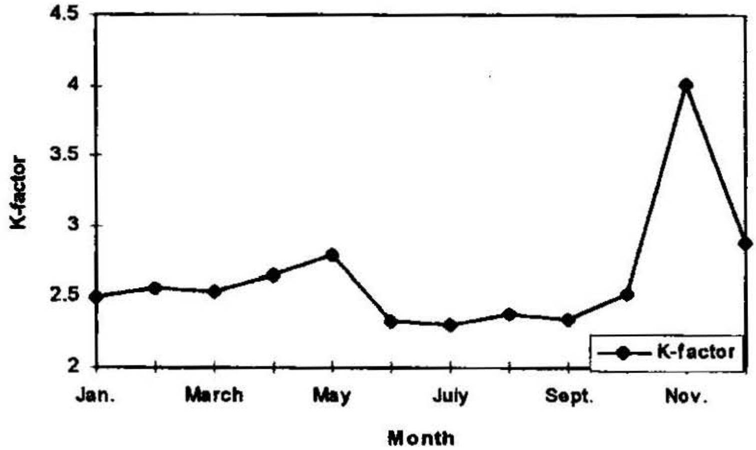

FIGURE 3. The K-factor at Bandar Baru Bangi in 1994

TABLE 1. The maximum and the minimum K-factor values in Bandar Baru Bangi

Year	Maximum K-factor	Minimum K-factor
1993	2.9488	2.422
1994	4.014	2.2981

MICROWAVE RADIO SOFTWARE

Computer aided design packages have been developed to meet the needs of the telecommunication community. The development involves the designing of line-of-sight microwave communication. The microwave radios have traditionally been focused on the improvement of spectrum utilization efficiency, achievement of large capacity, reduction of transmission cost, and so on. However, the reduction of total cost of the towers is sometimes omitted. In this research, a software package for optimizing the microwave radio link by optimizing the antenna height is developed. This software package will give an optimal antenna height that highly affects the total cost of the microwave link construction.

The development and implementation of microwave radio are progressing very rapidly. Microwave radio systems have also been widely used in the long-haul transmission systems for commercial TV and public telephone networks. In 1989 the number of microwave radio stations in Japan was 2000 (Shinji et al. 1989).

The rapid growth of microwave radio needs a lot of work and calculation in order to design and plan a good radio link, such as the microwave radio network in Japan. The software package of wave propagation helps the engineers to design such large networks. On the other hand, the software has to be updated regularly following the general development in this field. The optimization program helps to reduce the total cost of such big projects.

Many countries have their own software packages to deal with wave propagation calculation. For example, CVR is used by the United State of

America (USA) and Wave Propagation Calculator (WPC) is used by Hungary and other countries. In this paper, the Universiti Kebangsaan Malaysia-Wave Propagation Calculation and Link Optimization Software (UKM-WAPCALO) is designed for use in Malaysia. The antenna cost optimization program (ACOP) which is a part of UKM-WAPCALO, can optimize the project cost by optimizing the antenna height.

The design of the large microwave radio networks will become easier like the one in Japan. In addition to that, this software package, which is based on menus and icons, provides useful aid to the new graduate engineers. To operate the software the experience required is minimal.

In UKM-WAPCALO, numerous geographical related data are needed to study the VHF, UHF and microwave propagation. Information on administrative boundaries, population distribution, roads, power line networks are also required.

THE ANTENNA COST OPTIMIZATION PROGRAM DESCRIPTION

The antenna cost optimization program (ACOP) is written in Turbo Pascal 6.0. The path profile is generated in ACOP, while the transmitting antenna height is set by the user, the optimal height of the receiver is determined according to first Fresnel zone ellipse clearance.

ACOP is designed to optimize the antenna height for a line of sight microwave radio relay link, VHF and UHF. The development of the tool takes into consideration the format of the construction of the geographical database. Information on the cost evaluation of one antenna, the effect of the first Fresnel zone on the link and the database construction are required to develop ACOP.

ACOP consists of many procedures. The main program is the procedure to display the results. The graphical functions are used to draw the path profile and the first Fresnel zone ellipse. Figure 4 shows the flow chart of

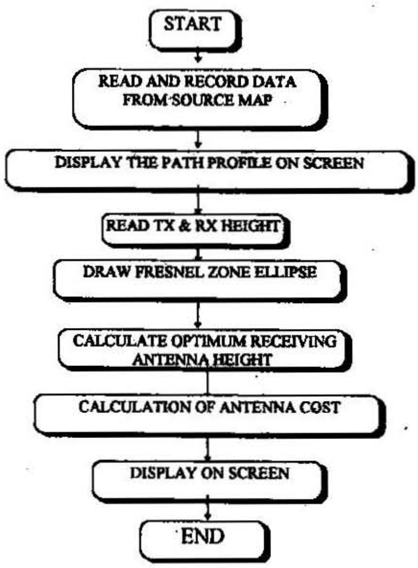

FIGURE 4. ACOP Flowchart

the main program. At start up, a screen consisting of different menu points will appear as shown in Figure 12c.

The output of the program displays information about the link. Figures 5 and 6 shows the output of ACOP for two different frequencies. Figures 7, 8 and 9 show the optimal receiving antenna height for 1, 10 and 100 GHz respectively as set by the user. Figure 10 and Figure 11 shows the output of ACOP when different terrain profiles are used.

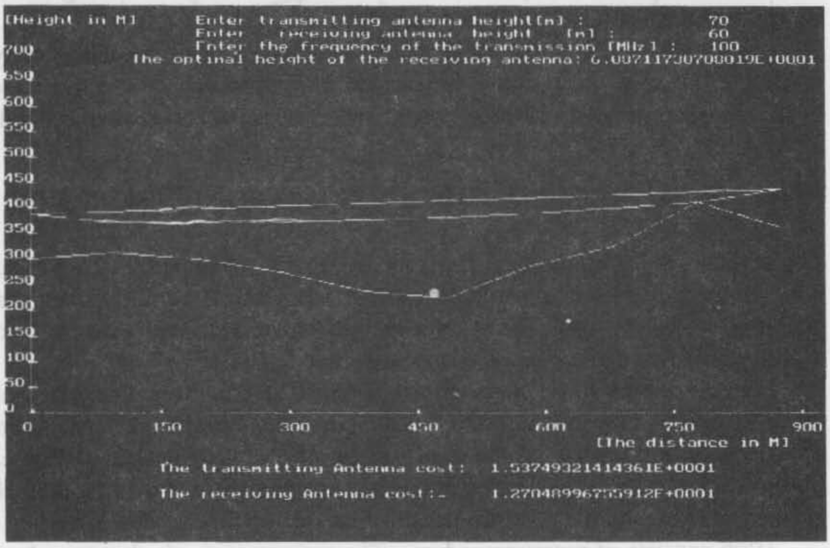

FIGURE 5. The output of the ACOP. Example 1

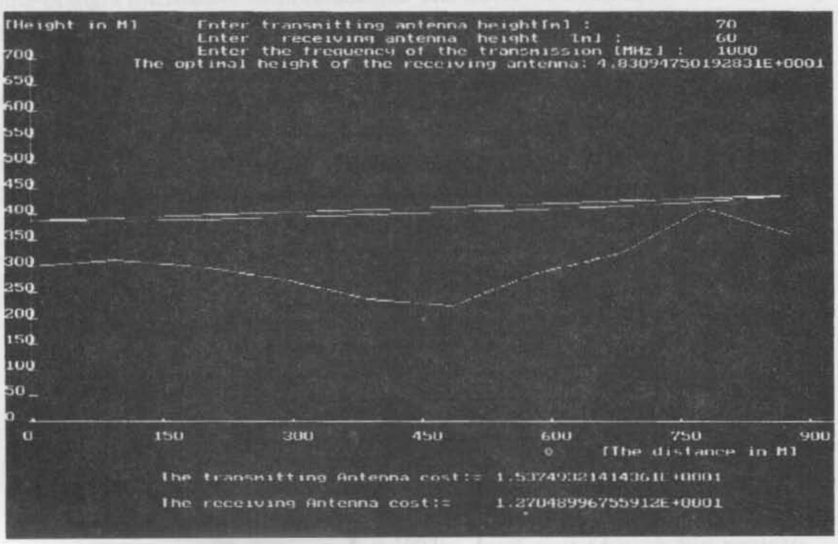

FIGURE 6. The output of ACOP. Example 2

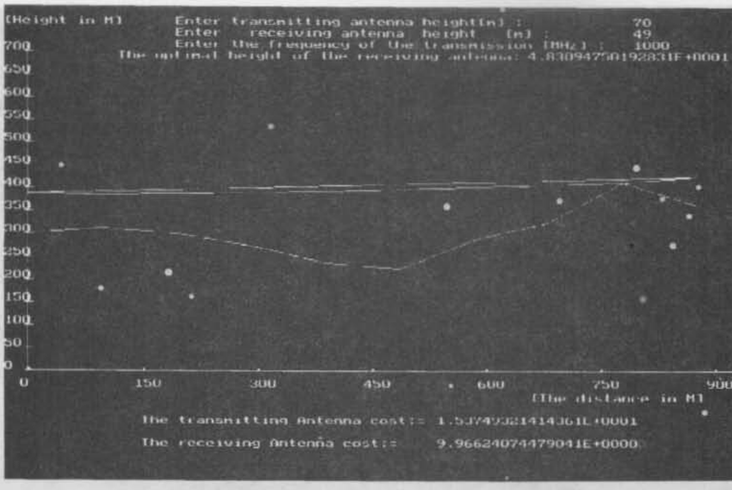

FIGURE 7. The output of ACOP. Example 3.

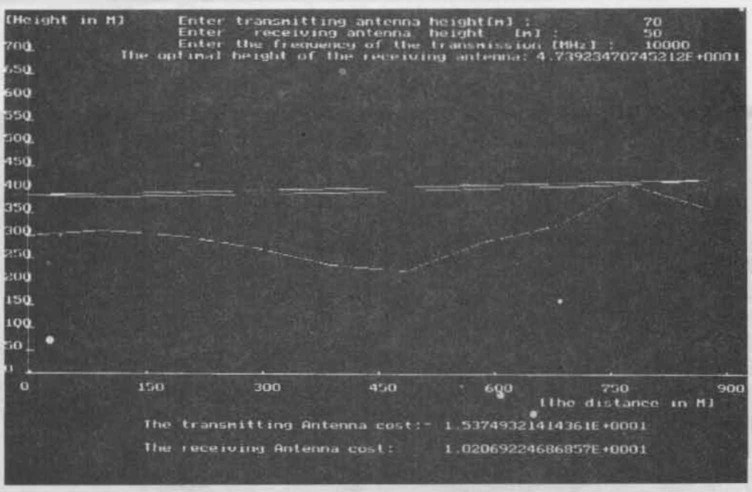

FIGURE 8. The output of ACOP. Example 4.

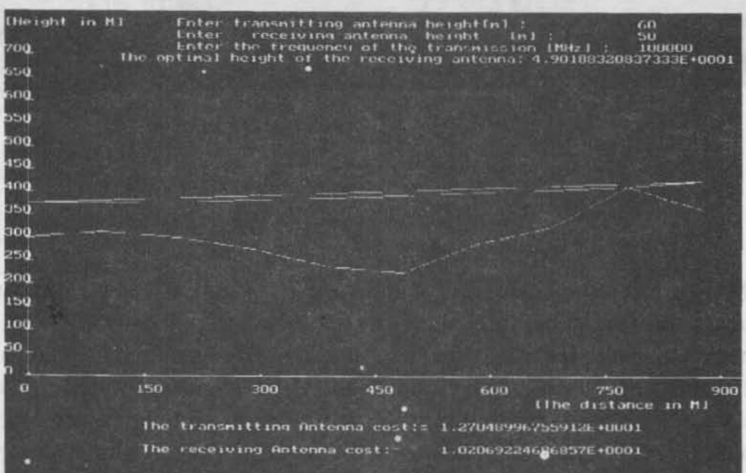

FIGURE 9. The output of ACOP. Example 5.

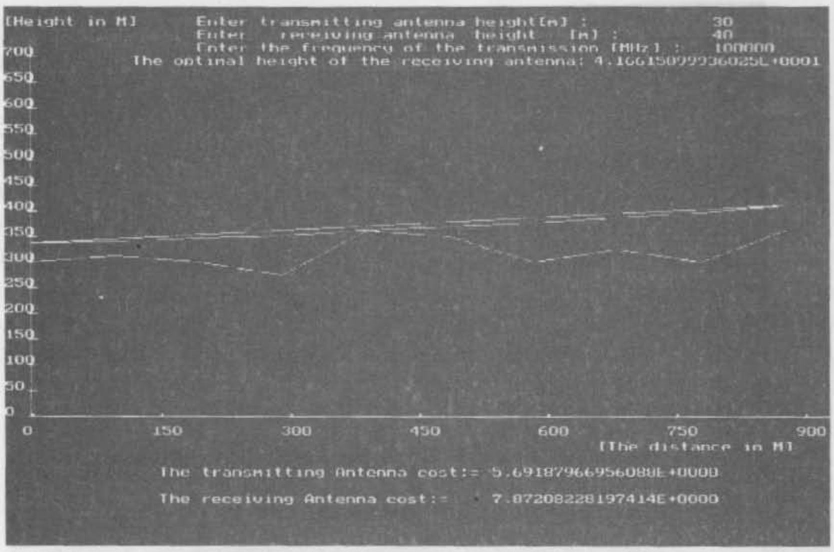

FIGURE 10. The output of ACOP. Example 6.

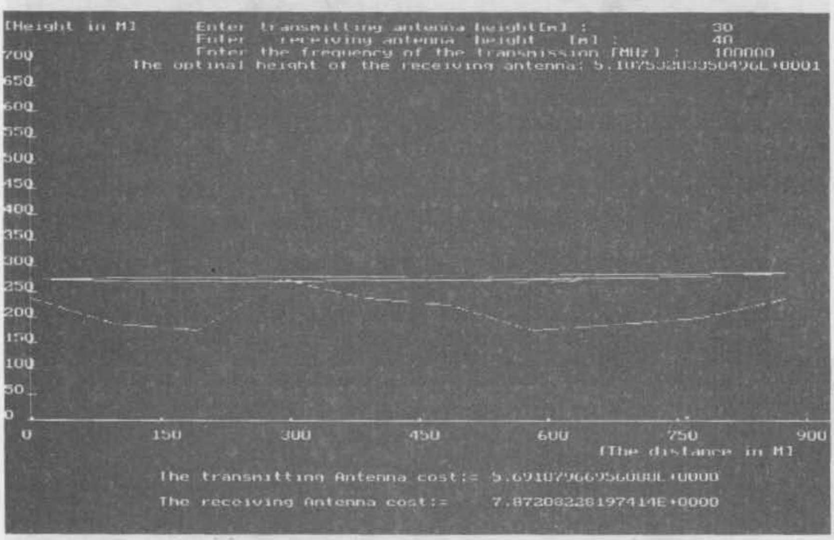

FIGURE 11. The output of ACOP. Example 7.

THE MICROWAVE PROPAGATION CALCULATION AND LINK OPTIMIZATION PROGRAM DESCRIPTION

This software package deals with wave propagation calculation such as terrain profile generation, microwave point-to-point calculation, path attenuation and calculation of antenna cost by using an optimization technique. This program is interactive and is based on menus and icons. The user selects desired options by using the mouse as a pointing device to choose menu points and types in parameter values to prompts. A plotter or a printer is necessary to present the results in a hard copy form. Numerous geographical related data are needed to evaluate the effects of VHF/UHF signal propagation. In addition to this, information on administrative boundaries, population distribution, roads, power line networks, and so on, are also required.

The basic icons and windows are written in Visual Basic 3.0 while executable files are generated by Turbo Pascal 6.0. The executable files are linked to the icons. The graphical data are linked to the picture boxes. Figure 12a, 12b and 12c show examples of WAPCALO display menu.

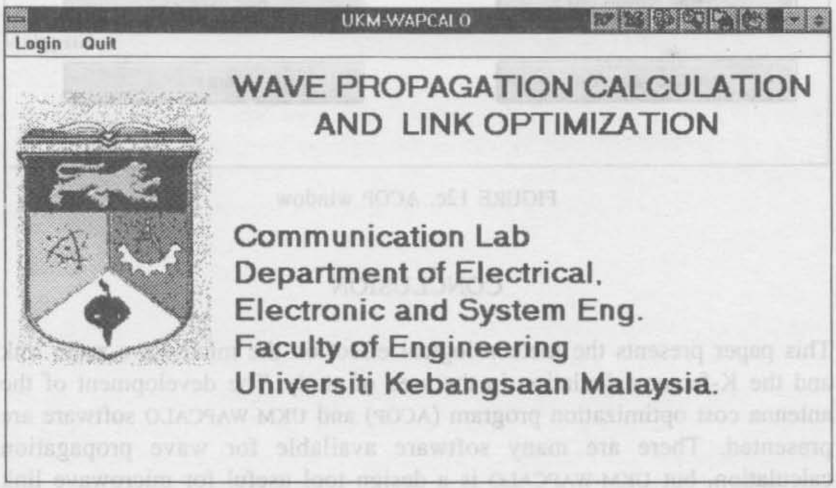

FIGURE 12a. The login window of UKM-WAPCALO

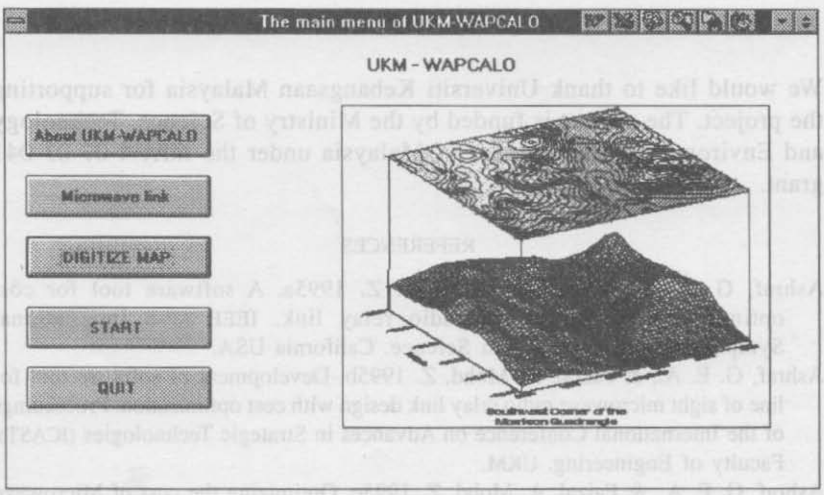

FIGURE 12b. The main window

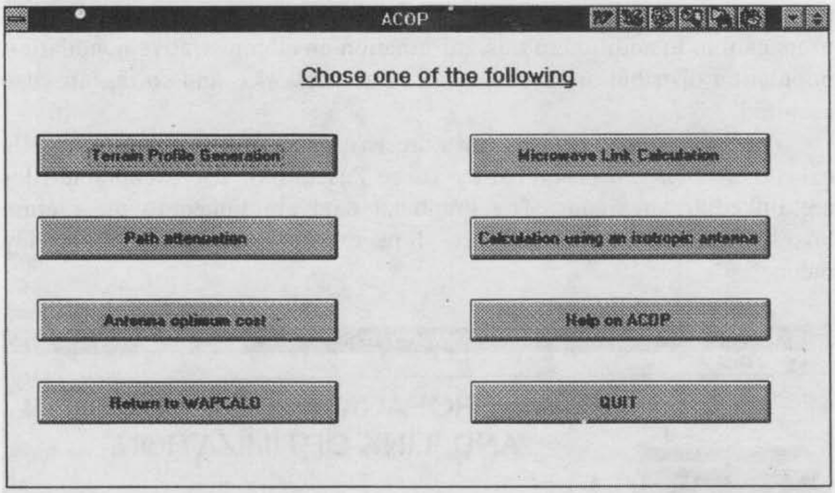

FIGURE 12c. ACOP window

CONCLUSION

This paper presents the meteorological effect on the microwave radio link and the K-factor calculation in the area of study. The development of the antenna cost optimization program (ACOP) and UKM-WAPCALO software are presented. There are many software available for wave propagation calculation, but UKM-WAPCALO is a design tool useful for microwave link and wave propagation calculations which contain the antenna optimization and digitize map construction programs.

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