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Full Paper

ESTIMATION OF OPTIMAL FREQUENCY AND ANTENNAE LENGTH BETWEEN RESOURCE INTERFACE AND MOBILE TERMINAL IN WIRELESS ATM

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ABSTRACT

Wireless communication involves transmission through the air with possibility of wide area coverage. Major issues that affect data transmission in a wireless environment includes the integrity of the transmitted data and the attenuation in the transmission medium imposed through geographical coverage. In this study, a scalable solution was proposed for wireless transmission between a mobile terminal and a network printer.

The transmission modules, which include power supply, transmitter and the receiver were specified and designed using modular approach. The parameters, which determine the magnitude of attenuation experienced by the wireless transmission, were specified. The simulation was carried out using Microsoft Visual Basic 5.0 to determine the antennae length for a particular separation and transmission frequency. The maximum distance between the receiver and the transmitter was determined based on the antennae length and transmission frequency. To achieve realistic communication (at an attenuation of 72.95dB) at an antenna separation of 5km and 10km respectively the frequency was set below 172kHz and 87.4kHz and the necessary antenna length was set to 0.37m and 1.47m respectively.

The result of the simulation shows that any transmission frequency below 106MHz would be suitable for setting up a point-to-point link between the mobile terminal and the printer. It was observed that attenuation varies inversely with both the antenna separation and the transmission frequency.

The approach was found to support dynamic mobile terminal movement within a wider geographical range when its distance from the receiving antenna is very large without experiencing appreciable changes. Also attenuation changes with a varying high frequency transmission are negligible.

1. INTRODUCTION

Mobile Communications are now mature to offer packet switched and broadband services (Carla-Farbiana and Renato, 2002). Broadband and Mobile communications are perhaps the leading edge in telecommunications. Asynchronous Transfer Mode (ATM) is generally considered the most suitable transport technique for the Broadband Integrated Services Digital Network (B-ISDN). On the other hand, wireless communications have been developed to a level where services offered can be extended beyond voice and data, thus a combination of wireless communications and ATM has the potential of providing freedom of mobility with service advantages and QoS (Quality of Service) guarantee. A challenge of Wireless ATM (WATM) is to harmonise the development of broadband wireless system with B-ISDN/ATM and ATM Local Area Networks (LAN), and offer similar advanced multimedia, multi-service features for support of sensitive voice communications, LAN data traffic, video, and desktop multimedia applications to the wireless user (Nikos *et al.* 1998). The evolution of multimedia services coupled with increased capability of communication devices evokes a proliferation of high data rate indoor multimedia applications and services (Wang *et al.*2009).

Currently, a number of research activities are focusing on the topic of Wireless ATM. For example, Naghshineh and Acampora (1996) focused on Quality of Service Provisioning in Micro-Cellular Networks Supporting Multiple Classes of Traffic, while Mahmoud (1996) focused on a multiple access scheme for Wireless Access to a Broadband ATM LAN based on Polling and Sectored Antennas. The development of a flexible printer interface for mobile terminal in a wireless ATM was carried out in Aderounmu *et al.* (1999). The ATM-based transport architecture for multi-services wireless personal communication networks is developed in Raychaudhuri and Wilson

(1994), while Raychaudhuri, (1996) discussed Wireless ATM network; architecture, system design and prototyping. In Falconer, (1996) the idea of system architecture for broadband millimetre-wave access to an ATM LAN was proposed, while Umehira (1996) presented an ATM wireless access system for tether less multimedia services.

This paper focuses on the estimation of optimal transmission frequency and antenna length between resource interface and mobile terminal in a wireless ATM Network.

The rest of the paper is organised as follows. In the following section we describe the Architecture of WATM. In section three mathematical model representing free-space basic transmission loss and attenuation was described. Section four discusses the simulation and analysis of the results, while section five concludes the paper.

2. WIRELESS ATM ARCHITECTURE

The increasing importance of portable computing and telecommunication applications motivate the fast development of high-speed wireless networking technologies. Especially, with the increasing main stream role of multimedia, Laptops, Personal Computers, Personal Digital Assistants (PDAs) and Personal Information Assistants (PIAs) require communication techniques with higher and more flexible bandwidth. Because of the growing acceptance of ATM as a broadband networking standard, WATM is receiving more and more attention. WATM is just a wireless extension to access ATM broadband networks. The idea is to add another layer in the standard ATM architecture to handle the wireless access. Each ATM cell will have an additional header and or trailer. However, since wireless usually implies mobility a few extensions need to be added to the current architecture of ATM protocols. It has been shown that by introducing new wireless-specific protocol sub-layers (MAC and DLC) and mobility extensions, standard ATM protocols can support seamless wired and wireless networking. This makes it possible to provide end-to-end quality-of-service control and a uniform ATM application program interface (Raychaudhuri, 1996). The basic idea of wireless ATM is to use a standard ATM cell of 5 bytes header field with 16 byte payload for network-level functions instead of the standard 48 bytes payload and adding wireless header/trailer on the radio link for wireless-channel-specific protocol sub layers. The protocol stack is fully harmonized with that of Standard ATM. Therefore, the normal ATM services, such as E.164/IPOA addressing, virtual circuit multiplexing, cell priotization, congestion control, QoS, Q.293/Signalling can be used for mobile services.

According to Stallings (1997), WATM system reference model mainly contains the following major components;

- WATM terminal: the end –user device
- WATM terminal adapter : WATM interface at end user,
- WATM radio port : the radio interface to the fixed ATM network,
- Mobile ATM Switch : the access switch with mobility support
- ATM network: the standard fixed ATM network
- ATM host: a standard fixed ATM network

As mentioned in section 1, this paper focuses on the estimation of optimal transmission frequency and antenna length between resource interface and mobile terminal in a WATM network. In this paper an example of a mobile terminal is the WATM terminal while the resource interface may be any interface within the fixed ATM network.

3. MODEL DEVELOPMENT

The mobile terminal in this design sends out signals through a transmitter circuitry to a receiver circuitry some distance apart on a resource interface. The transmitter power generated is represented by P_t, gain by G_t, a distance d away. The receiver receives power P_r from transmitter with gains G_r. The received power is given by

$$P_r = (P_t/4\pi d^2)G_t G_r (c^2/4\pi f^2) \qquad (1)$$

In this paper we assume resource interface is the printer interface. Intuitively, the first term is the power transmitted spread over a region preferably a sphere of surface area $4\pi d^2$. The power falls as the square of the distance. The next term is G_t and G_r, the transmitter gain and the receiver gain respectively. The higher the gains, the higher the power received. The last term is *the* $c^2/4\pi f^2$ and it shows that the power received decreases as the square of the frequency. This is an important idea, since it makes a large difference as we move higher and higher in frequency. In terms of free space loss encountered A_o, we have

$$Pr = P_L G_L G_R A_o \qquad (2)$$

Where the free space loss = $A_o = (4\pi d\, f/c)(4\pi df/c)$

Ultimately to receive the signal successfully, the required signal to noise ratio at the receiver must be achieved. There is need to express the above equations in terms of required signal to noise ratio. Hence the required Signal-to-noise ratio (S/N) is given by:

$$S/N = Pr/Nr = PtGtGr/AoNr \qquad (3)$$

With a point-to-point link it is preferable to calculate the free-space attenuation between isotropic antennas, also known as the free-space basic transmission loss (symbols: *Lbf* or A_0), as follows:

$$L_{bf} = 20 * \log\left(\frac{4\pi d}{\lambda}\right) \text{ dB} \qquad (4)$$

where:

L_{bf} : free-space basic transmission loss (dB)
d : distance
λ : wavelength, and
d and λ are expressed in the same unit (m).

Equation (4) can also be written using the frequency instead of the wavelength.

$$L_{bf} = 32.4 + 20 \log f + 20 \log d \quad \text{dB} \qquad (5)$$

where:
f : frequency (MHz)
d : distance (km).

Also with no intervening obstacles, the maximum distance between antennas conforms to

$$d = 7.14\sqrt{Kh} \qquad (6)$$

where d is the distance between antennae in kilometer, h is the antenna length in meters, and k = 3/2 is an adjustment factor.

Using (4), the free-space basic transmission loss is given by

$$L_{bf} = 20 * \log\left(\frac{4\pi d}{\lambda}\right) \text{ dB}$$

The existing design in (5) can cover a geographical radius of a maximum of 1km, which fixed d at 1000m; at a transmission frequency of 106MHz. But, for electromagnetic radiation we have

$$c = f\lambda \tag{7}$$

where

$c = 3 * 10^8 \text{ ms}^{-1}$ (speed of light)

f = transmission frequency

λ = wavelength of transmission

$$\therefore \lambda = c/f \tag{8}$$

substituting the above parameters in equation (8)

λ yielded 2.83m

Using (6), the attenuation is given by:

$$L_{b106} = 20 * \log\left(\frac{4\pi(1000)}{2.83}\right) \text{ dB} = 72.95 \text{ dB} \tag{9}$$

this shows the designed receiver cannot tolerate a signal attenuation greater than an approximate value of 72dB.

4. SIMULATION AND ANALYSIS OF RESULTS

Figure 1 shows attenuation variation of the transmission at various transmission frequencies for an antenna separation distance of 1km. From (9) it could be seen that any transmission frequency below 106MHz would be suitable for setting up a point-to-point link between the mobile terminal and the printer.

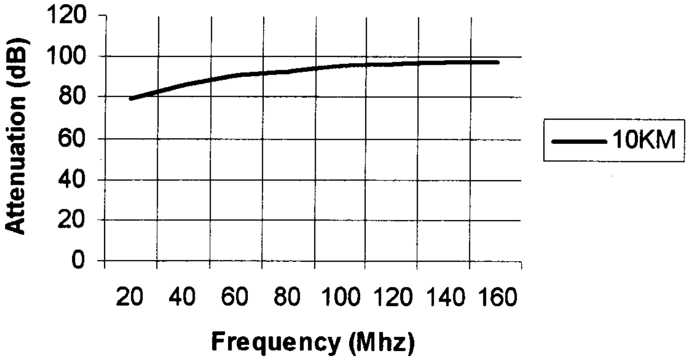

Figure 1: Attenuation variation against frequency for separation of 10km

The rate of attenuation variation with antenna separation and frequency is shown in Figure 2 and Figure 3. Figure 2 depicts attenuation varying inversely with antenna separation (distance) for 5 different distances, while Figure 3 shows attenuation variation with the transmission frequency for 5 different frequencies as well. By interpretation, a mobile terminal may move within a wider geographical range when its distance from the receiving antenna is very large without experiencing appreciable attenuation changes. Also attenuation changes with a varying high frequency transmission are negligible.

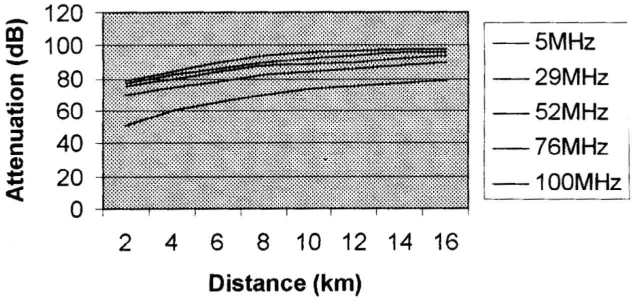

Figure 2: Attenuation against distance

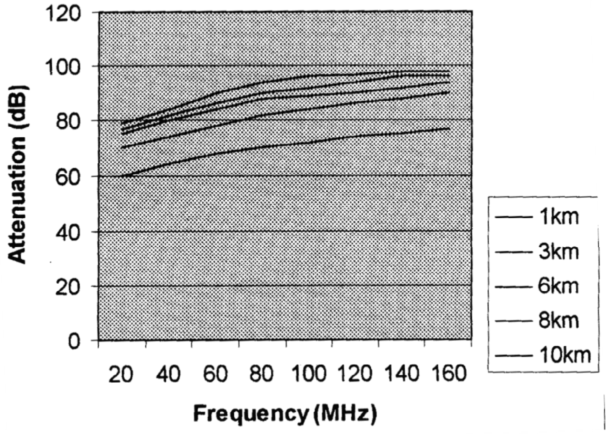

Figure 3: Attenuation against frequency

Similarly, from equation (9), for communication to be realistic (at an attenuation of 72.95dB) at an antenna separation of 5km and 10km respectively, the tolerable frequency ranges are set to below 172kHz and 87.4kHz respectively. The necessary receiving antenna lengths from equation (6) for these scenarios are 0.37m and 1.47m respectively. It can therefore be deduced that for larger antenna separation, a lower transmission frequency is required, and longer receiver antenna length is required. Also, the rate of attenuation variation with antenna separation and frequency can be shown. This will be of value when designing an adaptive data transmission system for a dynamic or mobile wireless network.

Given that:

$$L_{bf} = 20 * \log\left(\frac{4\pi d}{\lambda}\right)$$

from (4); converting to natural logarithm representation, we have

$$l = 20\ln(4\pi d/\lambda)/\ln(10)$$

$$= 46.052\ln(4\pi d/\lambda) \text{ .}$$

the rate of variation in attenuation with antenna separation is given by:

$$\frac{\partial l}{\partial d} = 46.052\frac{\partial}{\partial d}(\ln(4\pi d/\lambda)) \tag{10}$$

$$=46.052/d \tag{11}$$

similarly:

$$\frac{\partial l}{\partial f} = \frac{46.052}{f} \tag{12}$$

It would be seen that attenuation varies inversely with antenna separation or transmission frequency, and diminishes as either parameter increases.

By interpretation, a mobile terminal may move within a wider geographical range when its distance from the receiving antenna is very large without experiencing appreciable attenuation changes. Also attenuation changes with a varying high frequency transmission are negligible.

Mathematically:

$$\lim_{f\to\infty} \frac{\partial l}{\partial f} = \lim_{d\to\infty} \frac{\partial l}{\partial d} = 0 \tag{13}$$

5. CONCLUSION

The conclusion in this paper is based on the result(s) of the simulation. Figure 1, shows Attenuation Variation against Frequency, the transmission at various transmission frequencies for an antenna separation distance of 1km and also it could be seen that any transmission frequency below 106MHz would be suitable for setting up a point-to-point link between the mobile terminal and the printer for a separation of 1 Km.

It is discovered that for communication to be realistic (an attenuation of 72.95dB) at an antenna separation of 5km and 10km respectively, the tolerable frequency ranges are set to below 172kHz and 87.4kHz respectively. The necessary receiving antenna lengths for these scenarios were found to be 0.37m and 1.47m respectively. It is thus seen that for larger antenna separation it is either a lower transmission frequency combined with longer receiver antenna length is required or a higher frequency with a moderate antenna length, which is preferable for portability.

The approach employed in this paper provides an excellent way of estimating optimal transmissions frequency and antenna length for resource interface and mobile terminal in a Wireless ATM network.

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