

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.

For more information visit www.intechopen.com



Building energy efficiency design for telecommunication base stations in Guangzhou

Yi Chen, Yufeng Zhang and Qinglin Meng

*State Key Laboratory of Subtropical Building Science, Department of Architecture, South China University of Technology
China*

1. Introduction

Telecommunication base stations (TBSs), which are the basis of the telecommunications network, consume more energy than other public buildings due to their high inner heat density and special operating schedule. The number of mobile phone users in China exceeds 500 million, and the telecommunications network has become the largest in the world, consisting of more than 100,000 TBSs. The annual energy consumption of the network is 20 billion kWh, one third of which is used by TBSs. Guangzhou, as one of the fastest developing cities in China, has more than one thousand existing TBSs and the total annual electricity bills are in the tens of millions of RMB, 25% of which is the cost of air conditioning. With the rapid growth of telecommunications, energy conservation for TBSs is gaining greater attention in China.

Previous studies on energy conservation in TBSs mainly focused on improvement of efficient air-conditioning systems (Nakao et al., 1988; Maeda et al., 2005; Choi et al., 2007), indoor airflow optimization (Hayama & Nakao, 1989; Dan & Matti, 2000), use of renewable energy (Makhkamdjano, 2006), and other energy saving and monitoring techniques (Schmidt & Shaukatullah, 2003). There are very limited studies on building energy efficiency design of TBS. Building energy efficiency design, which is known as passive cooling technology, is very popular in the traditional buildings and well inherited and applied in the modern buildings in Southern China. Compared with the active one, such as air-conditioning, passive cooling technology has notable advantages on utilizing natural cooling capacities with no or few energy consumption. Many studies report building energy efficiency designs of walls, roof, glazing, shading and natural ventilation for residential buildings (Feng, 2004), institutional buildings (Athanasios et al., 2007) and high rise apartments (Cheung et al., 2005), however, no such studies were performed on TBS buildings. Nakao et al. (Nakao et al., 1988) studied a thermal control wall for TBS, which can lose heat by using a two-phase loop-type thermo-siphon system integrated inside the wall. The heat transmission coefficient of the wall was found to be one to ten times of the ordinary wall and the annual energy saving was estimated to be 20%. The study proposes a new energy efficiency design of wall for TBS, however, no other designs, such as shading or natural ventilation were mentioned.

This chapter reports the study on building energy efficiency design for TBSs in Guangzhou. Through field investigation of a typical TBS in Guangzhou, the basic information of TBS was achieved, the key factors influencing energy consumption of TBS were determined and several building energy efficiency designs were proposed. The effect on the annual cooling load for each energy efficiency design was analyzed and a combined effect was achieved for several combinations of the designs by building simulation. The building energy efficiency design strategy for TBS in Guangzhou was concluded. It was found that ventilation design is the primary choice for energy efficiency TBS building design. A new ventilation cooling technology (VCT) was proposed. Based on the field investigation, the application feasibility of VCT was studied systematically and the optimization of airflow organization for VCT was analyzed.

2. Field investigation

2.1. Climate conditions in Guangzhou

Guangzhou is located at latitude 23°08'N and longitude 113°19'E. Summer is hot and humid and winter is warm. The average air dry-bulb temperature is 28.4 °C in July and 13.3 °C in January. The mean daily temperature variation is 7.5 °C. The relative humidity is about 83% in summer and 70% in winter. The average annual rainfall is about 1705 mm of which 80% falls between April and September. The long, hot and humid summer in Guangzhou creates a huge demand for energy for cooling.

2.2. Field investigation methods

A typical TBS in Guangzhou was chosen for investigation. The TBS is located on the top of a library, with dimensions of 4.66 m long × 4.66 m wide × 2.8 m high. The plan view of the typical TBS is shown in Figure 1. The structure and conductive thermal resistance of the building envelopes of the typical TBS are shown in Table 1. Two air conditioners are installed for cooling with a temperature set point of 25 °C. The telecommunication equipment and the air conditioners work continuously, 24 h per day and 365 days per year. There is no window on the walls, mainly for the safety of the telecommunication equipment.

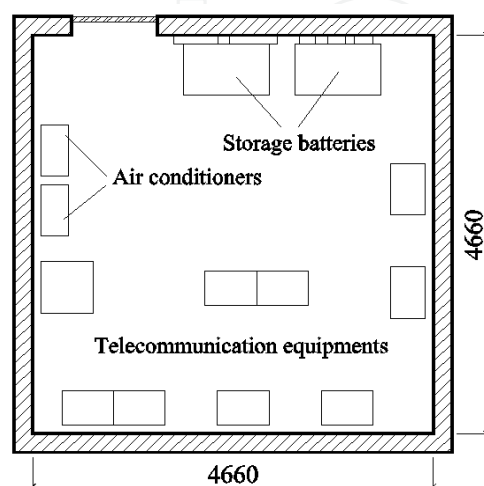
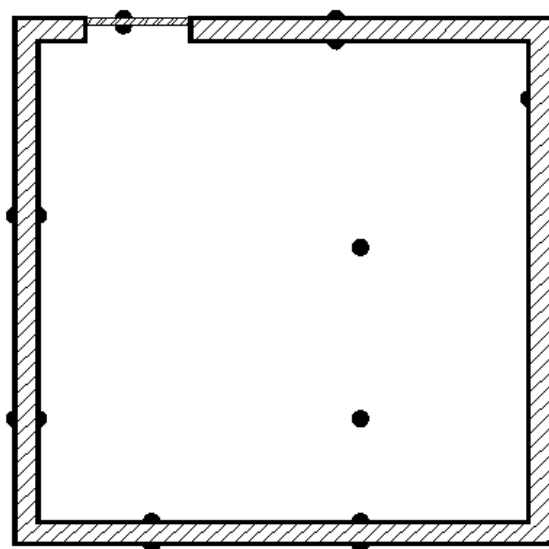


Fig. 1. Plan view of a typical TBS.

Building envelope	Structure	Conductive thermal resistance ($\text{m}^2\text{K}/\text{W}$)
Walls	External cement/sand plaster (20mm) Lime-sand brick (180mm) Internal gypsum plaster (20mm)	0.210
Roof	Polyurethane foam plastics (50mm) Internal gypsum plaster (20mm)	1.376
Floor	External cement/sand plaster (20mm) Reinforced concrete (100mm) Internal gypsum plaster (20mm)	0.104

Table 1. Structure and conductive thermal resistance of the building envelopes of the typical TBS.

The thermal characteristics of the building envelopes, the heat dissipation of the telecommunication equipments and the performance of the air conditioners were investigated through physical measurements. The measurements were carried out during the winter in Guangzhou from 18:00 h on January 8 to 13:00 h on January 10 (44 h in total). Measurements taken included the interior and exterior surface temperatures of the walls, roof and floor (Figure 2), the exterior surface temperature of the equipments, the velocity and temperature of the air exhausted from the equipments (Figure 3), the ambient room air temperature, and the return and supply air velocities and temperatures of the air conditioners. The temperature was measured using thermocouples with an accuracy of ± 0.5 °C and recorded by a data logger at 5 min intervals. Air velocity was measured by a heated-sphere anemometer with a range of 0.1-30 m/s and an accuracy of $\pm 5\%$. The energy consumption of the TBS was measured using a power meter.



- measuring positions of the walls
- measuring positions of the roof and floor

Fig. 2. The measuring positions on the building envelopes.

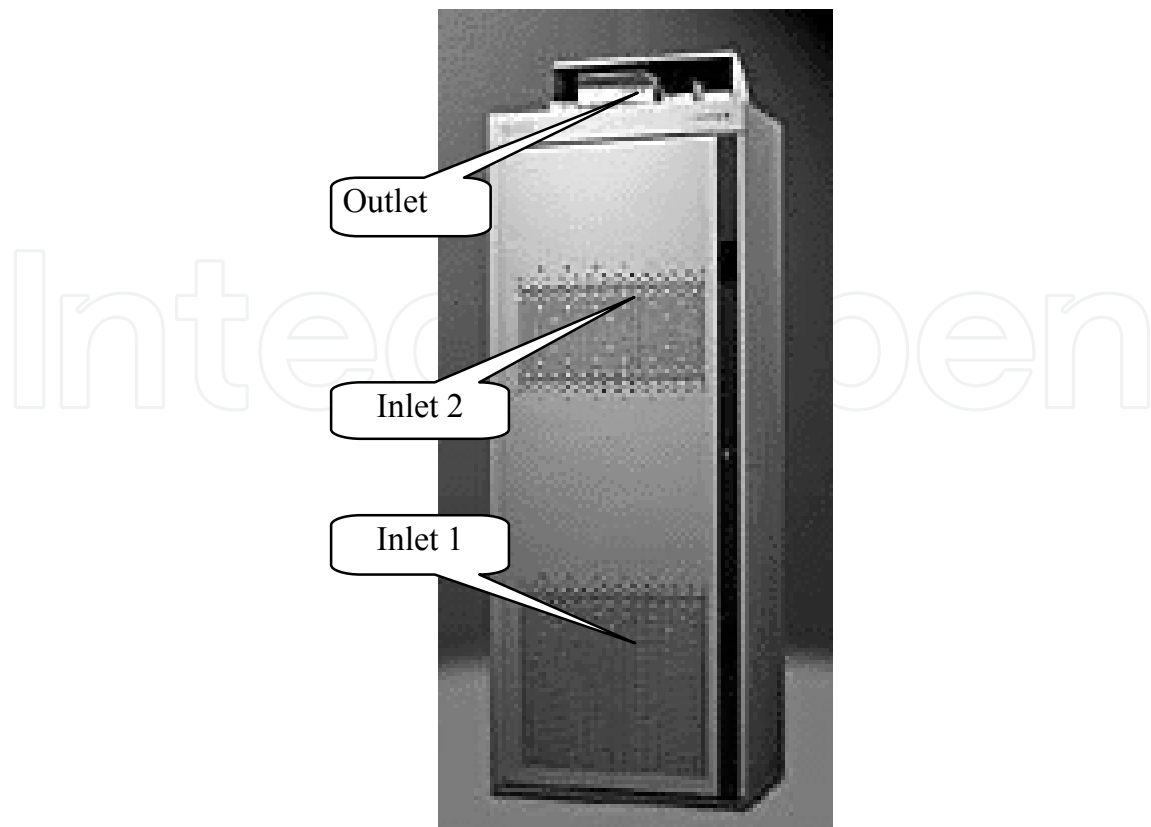


Fig. 3. Telecommunication equipment measurements.

2.3. Field investigation results

2.3.1. Inner heat source

Heat loss of the telecommunication equipments is the main inner heat source for the TBS, which can be transported by convective and radiative ways. The convective heat loss was calculated by using the airflow rate, ambient room air temperature (i.e. inlet air temperature) and outlet air temperature. The radiative heat loss was calculated by using the exterior surface temperature of the equipments and the interior surface temperatures of the envelopes. It was found that the total heat loss of the equipments was maintained constant at a level of 4.35 kW, regardless of communication work loads or outdoor weather conditions. The density of the inner heat source was about 200 W/m², which is much larger than the normal public buildings.

2.3.2. Thermal performance of building envelopes

Figure 4 shows the measured results of the south wall. Outdoor air temperature obtained from the local meteorological observatory in Guangzhou is included in Figure 4 as well. The interior surface temperature, mainly influenced by the indoor air temperature, was comparatively stable (around 25 °C). The exterior surface temperature, affected by the outdoor air temperature and solar radiation, fluctuated greatly with time from 12.5 to 37.5 °C. The mean outdoor air temperature was 12.8 °C and the highest was only 18.3 °C during the measuring period.

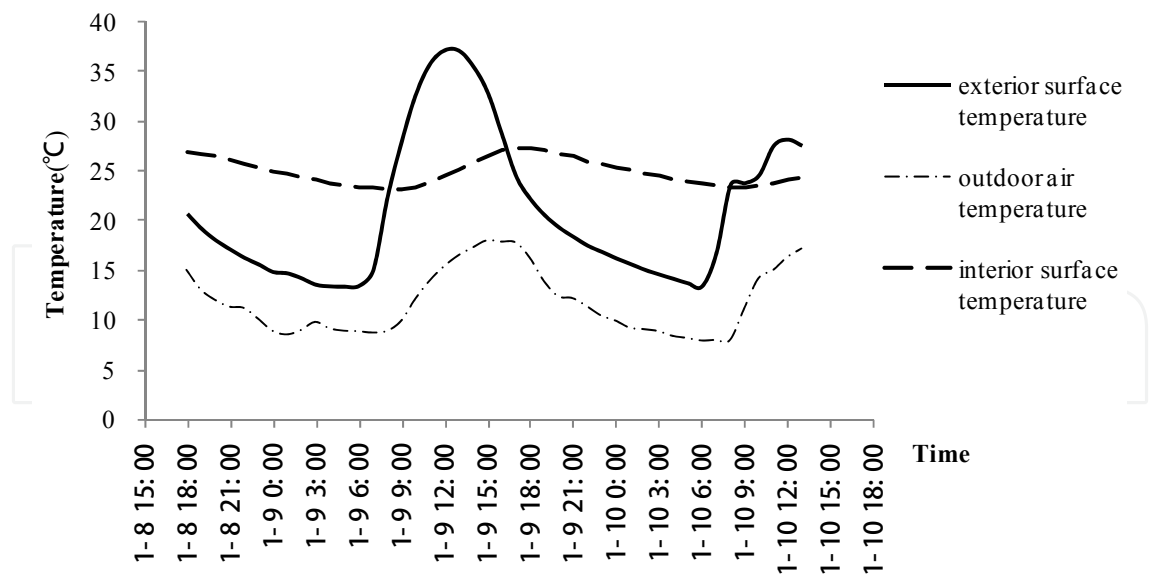


Fig. 4. Temperatures of interior and exterior surface of the southern wall and outdoor air temperature change with time.

It was decided to use the steady state heat transfer equation to make an initial observation on the variation of the heat transfer amount and direction, rather than the dynamic equation, which is relative complicated. The steady state heat transfer equation is:

$$Q = (\theta_e - \theta_i) / R \times S \tag{1}$$

where Q is the total heat transfer (W), θ_e is the exterior surface temperature (°C), θ_i is the interior surface temperature (°C), R is the conductive thermal resistance ($m^2 K/W$) and S is the area (m^2) of the building envelopes. Based on the thermal characteristics (see Table 1) and the measured temperatures, heat transfer of each building envelope was calculated and shown in Figure 5.

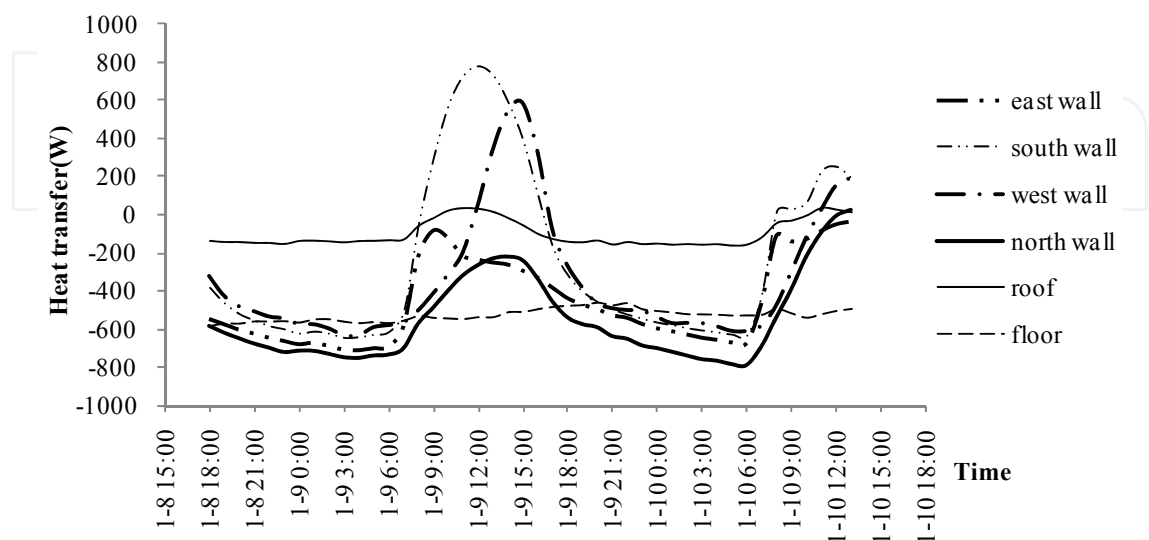


Fig. 5. Heat transfer change with time for each building envelope.

The variation of heat transfer with time was slight for the roof and floor, and large for the walls, especially for the south wall. Guangzhou is located in the northern hemisphere and the sun lies in the southern sky during the measurement, so the south wall gained more heat from solar radiation than the roof and the other walls, resulting in the largest heat transfer change with time. The heat gain (heat transfer from outdoor to indoor) was highest at noon for the south wall and roof and at 15:00 for the west wall. The heat loss (heat transfer from indoor to outdoor) was highest at 7:00 for all the envelopes.

The heat transfers of all the building envelopes were summed up and the change of the total heat transfer with time is shown in Figure 6. In the period of the investigation, the time for the building envelopes to gain heat is only 2 h and to lose heat in the rest of 42 h. Moreover, the maximum of hourly heat loss (3444 W) is far more than the one for heat gain (114 W). The building envelopes of the TBS works in most of time together with the air conditioners to discharge the inner heat generated by the telecommunication equipments and gains heat in only very short time due to the strong solar radiation.

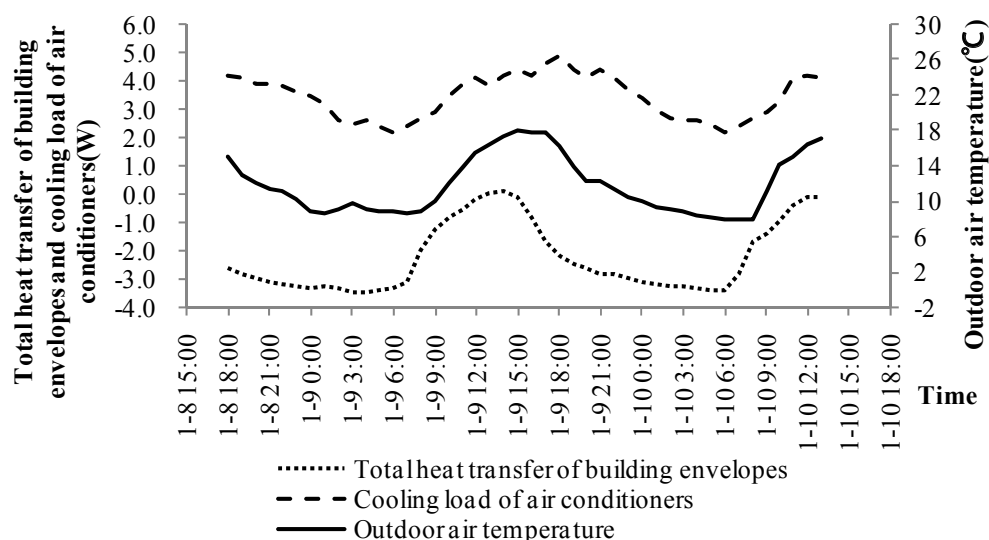


Fig. 6. Total heat transfer of building envelopes, cooling load of air conditioners and outdoor air temperature.

The cooling load of the air conditioners was calculated by using the measured results of the return and supply air temperature and airflow rate. The change tendencies with time are very similar for the cooling load of the air conditioners, the total heat transfer of the building envelopes and outdoor air temperature (see Figure 6). The lower the outdoor air temperature, the more the heat discharged by the building envelopes and the lower the cooling load of the air conditioners. Enhancement of the heat transfer of the building envelopes could save energy by decreasing the cooling load and shortening runtime of the air conditioners.

Figure 7 shows the measured results for the single-phase electrical power of the TBS. Electrical power was maintained at a low level from 5:10 pm to 5:45 pm on Jan 8. That is because the door was open during this period, and the heat was dissipated through the open door by natural ventilation. This shows that internal heat can be removed directly by ventilation, and thus the energy consumption for the air conditioning can be significantly reduced.

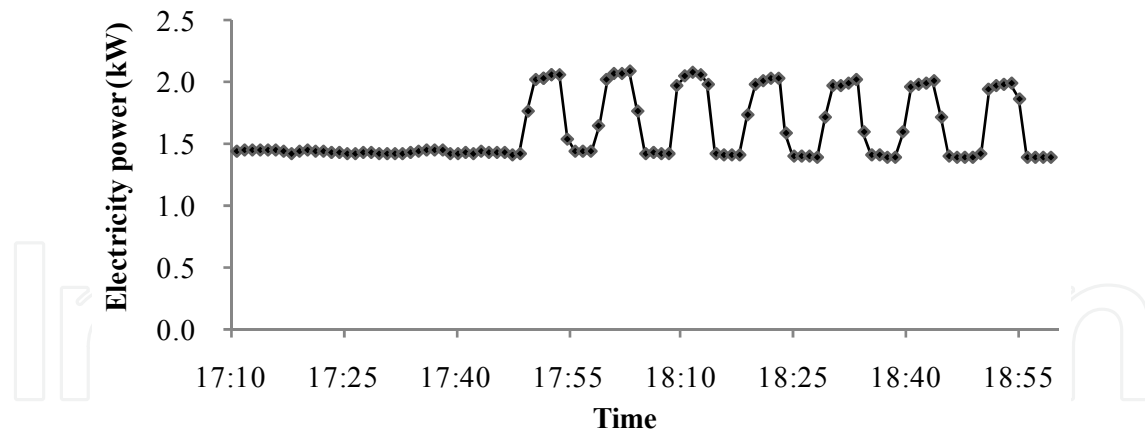


Fig. 7. Single-phase electrical power variation of the TBS with time.

The basic information of the TBS, including the thermal characteristics of the building envelopes, the inner heat density, the indoor air temperature set point, the operating schedule of equipments and air conditioners were achieved and the thermal performance of the building envelopes during the measuring period was studied by the field investigation. Based on this information, building simulation was applied to study the thermal performance of the TBS for a whole year and estimate the energy saving potentials for each building energy efficiency design.

3. Building simulation

3.1 Simulation methods

A dynamic thermal simulation program named DeST was applied to estimate the annual cooling load of the typical TBS. DeST was originally developed in 1989 by Tsinghua University in China based on the IISABRE simulation environment (Hong, et al. 1997) and validated by comparison with both well-known international thermal simulation programs (Bloomfield, 1994) and experimental results (Zhang, et al. 2004). DeST has become a reliable simulation program and is widely applied in building design and for national standards in many countries (Yan, et al. 2004).

Figure 8 shows the model of the typical TBS in DeST created according to the real plan of the TBS. The parameters for the simulations were set according to the basic information achieved by the field investigation. The structure and thermal characteristics of the building envelopes were set as in Table 1. The telecommunication equipments run all day with a total heat of 4.35 kW. The heat density of the lighting and the people were ignored due to the limited period of occupancy. The air conditioners operated continuously with a temperature set point of 25 °C and a relative humidity set range between 5% and 85%. The ventilation rate between the outdoor air and the TBS room was 0.5 h⁻¹. The absorption coefficient of solar radiation of the exterior surfaces of the walls and roof was 0.7. Outdoor climate data was set according to typical Guangzhou annual meteorological data.

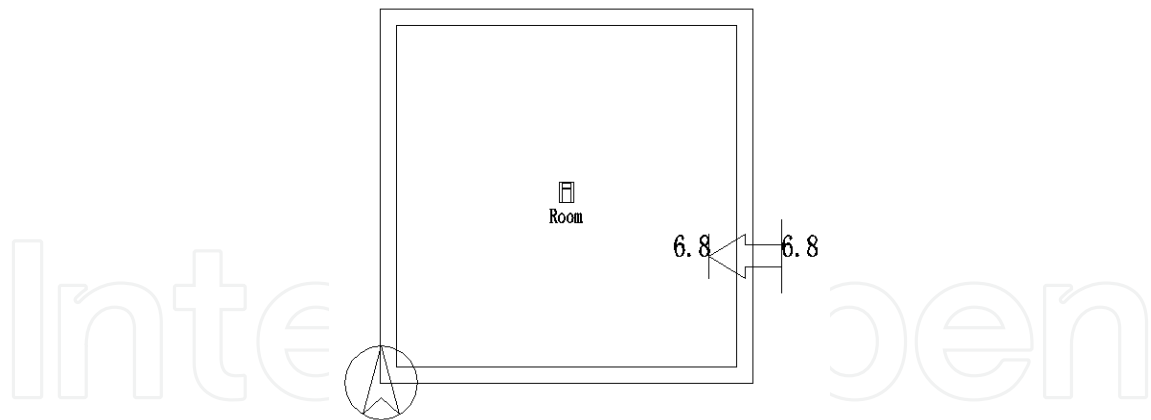


Fig. 8. Building simulation model for the typical TBS.

3.2 Simulation results and discussion

Simulation on the performance of the investigated TBS shows that the accumulation of annual cooling load is 36891 kWh. It can be seen that 97% of the inner heat source becomes the cooling load of the air conditioners and only 3% is discharged by the building envelopes in the investigated TBS. Well building energy efficiency design, which enhances the heat dissipation by the building envelopes, can save energy consumption of cooling. Heat transfer coefficient and solar absorptance are the key factors determining heat transfer of building envelope. In addition, shading and ventilation, which are widely used in the hot and humid region of China, are considered as the potential energy efficiency designs for TBS as well.

3.2.1. Temperature set point adjustment

Thermal performance of building energy efficiency design is affected by many factors, such as inner heat density, operating schedule and environmental requirements. The information of these factors were obtained by the field investigation and directly inputted as the known conditions into building simulation, except for the indoor temperature set point. The temperature set point for the air conditioners in a typical TBS is 25 °C, which takes human comfort requirements into consideration. In practice, the time for which people are present in the TBS is so short that the comfort requirements can be ignored, and the indoor temperature set point of the TBS can be raised to 30 °C according to the environmental requirements of the telecommunication equipment (Standardization Institute of Posts and Telecommunications, 1995). The performance of the TBS with the adjustment of temperature set point was simulated and the results show that the annual cooling load is decreased by 21% compared with the one without adjustment. Meanwhile, the role of building envelopes becomes more important and their heat dissipation accounts for 23% of inner heat source. The following analysis on the building energy efficiency design is based on the model with the temperature set point adjustment.

3.2.2. Design of heat transfer coefficient

The heat transfer coefficients of the walls and roof can be varied from 0.5 to 6W/m² K when choosing different local materials and structures in Guangzhou. The simulation results show that (see Figure 9) the relationship between the annual cooling load and the change of heat

transfer coefficient is linearly and an increase in heat transfer coefficient is beneficial to the reduction of cooling load. The concept of better insulation saving more energy is not applicable to the special kind of buildings such as TBS in Guangzhou. The annual cooling load was found to be less sensitive to the change of heat transfer coefficient of the roof due to the strong solar radiation absorption of the roof during a whole year. Considering the practical available materials and structures in Guangzhou and safety of the communication equipments, the walls and roof were determined as 60mm reinforced concrete walls with plaster and 50mm reinforced concrete roof with plaster. The percentage saving in annual cooling load achieved by the designs is 11.8% and 3.1% separately.

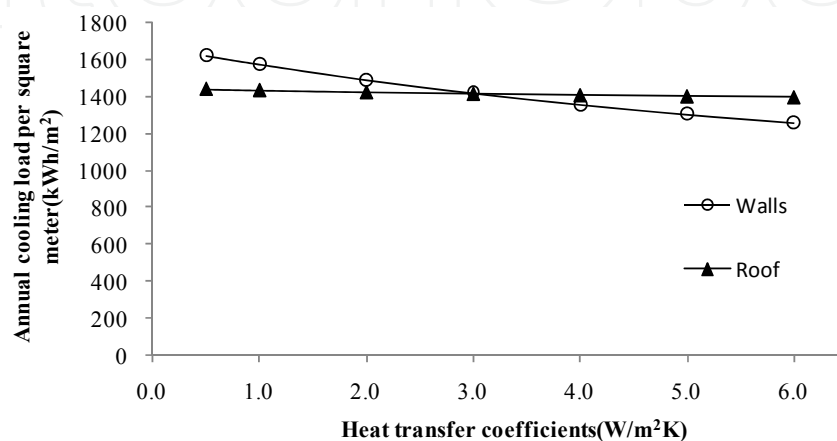


Fig. 9. Effect of heat transfer coefficients of walls and roof on annual cooling load.

3.2.3. Design of solar absorptance

The solar absorptance of the outside surface of the external walls and roof was changed from 0.7 to 0.1 to represent different external finishes. It was found that the annual cooling load has a linear relationship to the solar absorptance of the external surfaces, and the lower the solar absorptance, the higher the saving that can be achieved (see Figure 10). A reduction in solar absorptance from 0.7 to 0.1 can achieve a 7.5% and 1% saving in annual cooling load for the walls and roof separately. The design of shading on the walls or roof can be included into the design of solar absorptance by transforming the shading coefficient into the resulting solar absorptance.

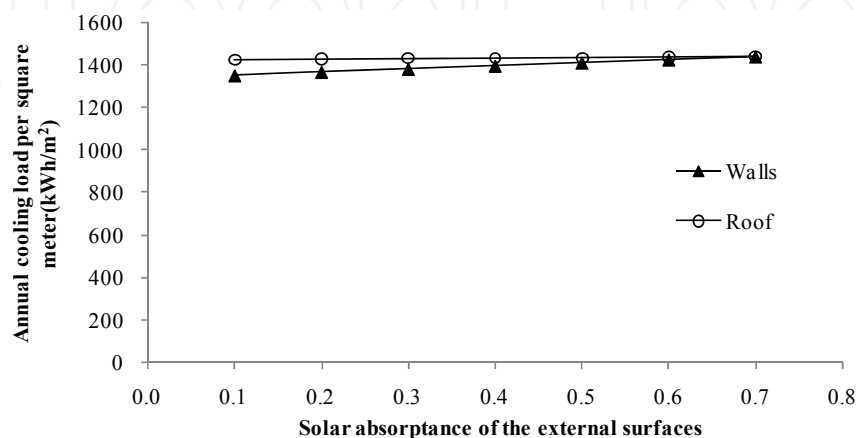


Fig. 10. Effect of solar absorptance of exterior surface of walls and roof on annual cooling load.

3.2.4. Ventilation design

The frequency distribution of outdoor air dry-bulb temperature in a typical year in Guangzhou is shown in Figure 11. The percentage of the time when outdoor air temperature is lower than the indoor temperature set point of TBS (30 °C) is more than 90%, which indicates a great potential of energy saving can be achieved by ventilation. Air exchange rate has a significant impact on cooling load. The ventilation rate between the outdoor air and the TBS room when applying VCT was changed from 0.5 h⁻¹ to 300 h⁻¹ and the annual cooling load was simulated, and is shown in Figure 12. The ventilation rate has a significant effect on the annual cooling load. When the ventilation rate increases from 0.5 h⁻¹ to 50 h⁻¹, the annual cooling load per square meter decreases from 1439 kWh/m² to 514 kWh/m² and the rate of decline is 64%. As the ventilation rate continues to increase, the annual cooling load does not reduce significantly, which indicates that a reasonable ventilation rate for VCT is 50 h⁻¹. The increase of air exchange rate can be achieved in practice by design of mechanical ventilation.

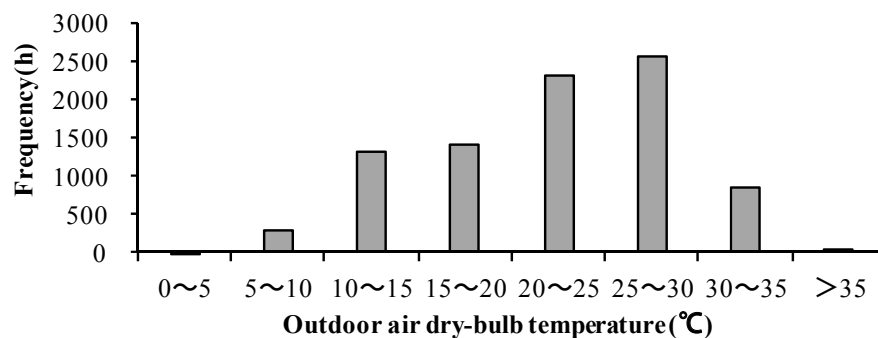


Fig. 11. Frequency distribution of outdoor air dry-bulb temperature in Guangzhou.

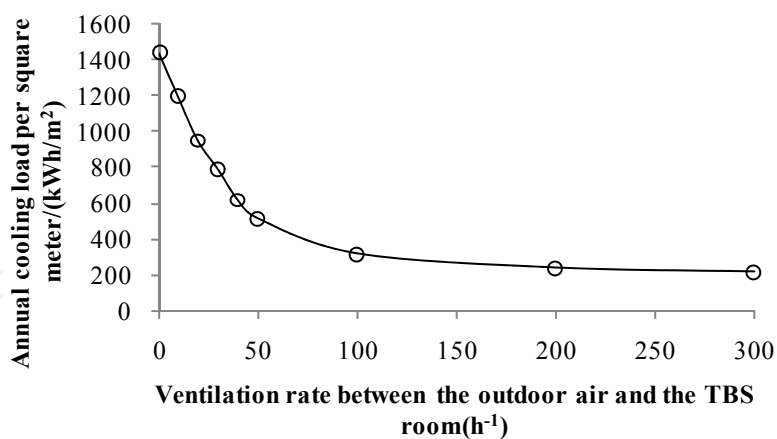


Fig. 12. Effect of ventilation rate on annual cooling load.

The internal heat in the TBS remains constant while the outdoor air temperature changes are comparatively large, and thus the time when the outdoor cold air can be used changes along with the outdoor air temperature. Figure 13 shows that the runtime of the air conditioners is greatly shortened by applying VCT. The air conditioners need to run year-round in a TBS without VCT, while they run mainly on a part-time basis from May to October in the TBS with applied VCT. The annual runtime of the air conditioners amounts to 2509 h, which accounts for only 29% of the total of 8760 h. Thus significant energy savings are made.

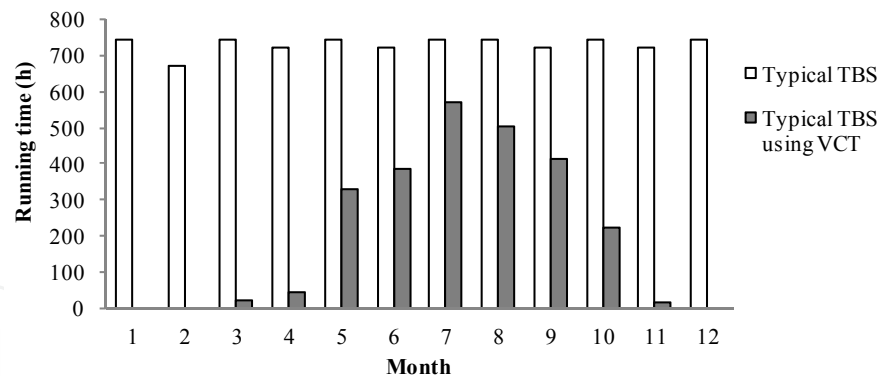


Fig. 13. Monthly runtime of air conditioners in a typical TBS and in a typical TBS using VCT.

3.2.5. Combinations of building energy efficiency designs

The savings of annual cooling load from various building energy efficiency designs are shown in Figure 14. It can be seen that ventilation design achieves the highest saving of more than 64.2%, followed by an 13.4% saving from heat transfer coefficient design of walls. The savings by using other energy efficient designs are less than 10%. The combination of the energy efficiency designs are always preferred and applied in practice to achieve a better thermal performance of a building. As the impact on energy saving may be strengthened or weakened by the combination, several possible combinations of the building energy efficiency designs were analyzed by using building simulation. The combined effect is approximately equal to the sum of the effect of each design for the combination of the designs of walls and roof (see Figure 15), which is because the impact of walls on cooling load can be considered independent from the one of roof. The combined effect is significantly greater than the sum for the combination of heat transfer coefficient design and solar absorptance design, which can be explained as followings: Not only the heat loss, but also the heat gain will increase with heat transfer coefficient design, and the latter one can be weakened by solar absorptance design, resulting in a higher energy saving. The combinations of ventilation design with others do not work much better than ventilation design, which is because that the most of inner heat source will be taken away through well ventilation and the impact of heat transfer of walls and roof becomes very slight.

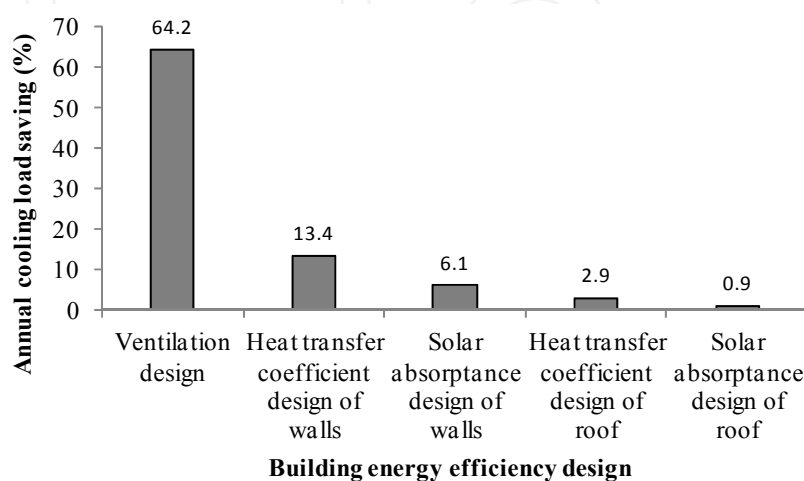


Fig. 14. Annual cooling load saving from various building energy efficiency design.

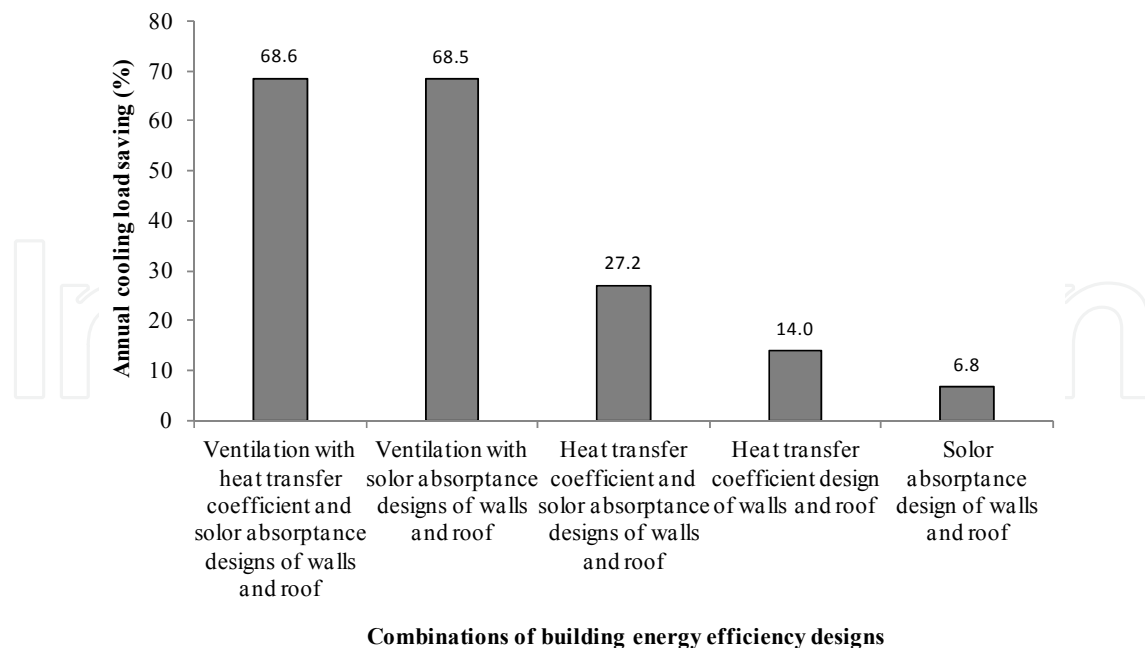


Fig. 15. Annual cooling load saving for combinations of building energy efficiency designs.

4. Study of ventilation cooling technology

It was found that ventilation design is the primary choice for energy efficiency TBS building design. However, there are no studies on TBS ventilation design for energy conservation to date. The envelopes of the existing TBSs are well sealed without any ventilation and the significant cooling capacity of outdoor air in winter, spring, autumn and morning and evening in summer is neglected, resulting in huge energy costs for air conditioning. To make full use of the natural outdoor cooling resources, a new ventilation cooling technology (VCT) was proposed. By applying VCT, the outdoor cold air is imported by fans to dissipate the internal heat of telecommunication equipment directly. The fans, which consume much less electrical power, are substituted for the air conditioners for environmental control when the temperature and humidity of the outdoor air meet the equipment requirements. The runtime of the air conditioners is thus greatly shortened, resulting in remarkable energy savings.

However, there are several practical problems for the application of VCT to the TBS such as: a control strategy for the fans and air conditioners for an environment with guaranteed temperature and humidity to ensure reliable operation of the equipment; the temperature and humidity of the environment itself in the TBS; chemically and mechanically active substances and their conditions in the TBS; the condensation risk on the internal surfaces of the building envelopes; additional costs for reconstruction and the payoff period. Therefore, a feasibility analysis for VCT relative to the above problems should also be carried out.

4.1 Feasibility analysis

4.1.1 Control strategy

Figure 16 shows a schematic drawing of the VCT applied in the typical TBS. The fans and filters are installed on the exterior walls. Air conditioners are also installed as auxiliary

cooling equipment to guarantee the environmental temperature and humidity requirements. There are three situations where the fans and air conditioners are controlled by the control system, i.e.: the fans and air conditioners are both switched off; the fans are switched off and the air conditioners are turned on; and the fans are switched on and the air conditioners are turned off. Figure 17 shows the control strategy for the VCT. If the indoor temperature T_i is lower than the temperature set point of T_{acs} , the fans and air conditioners are both switched off. Otherwise, if the outdoor temperature T_o is higher than the set point of T_{fs} or the indoor relative humidity Φ_i is higher than the set point of Φ_s , the air conditioners are turned on and the fans are switched off. However, if T_o is lower than T_{fs} and Φ_i is lower than Φ_s the air conditioners are turned off and the fans are switched on. These cycles are repeated at regular intervals.

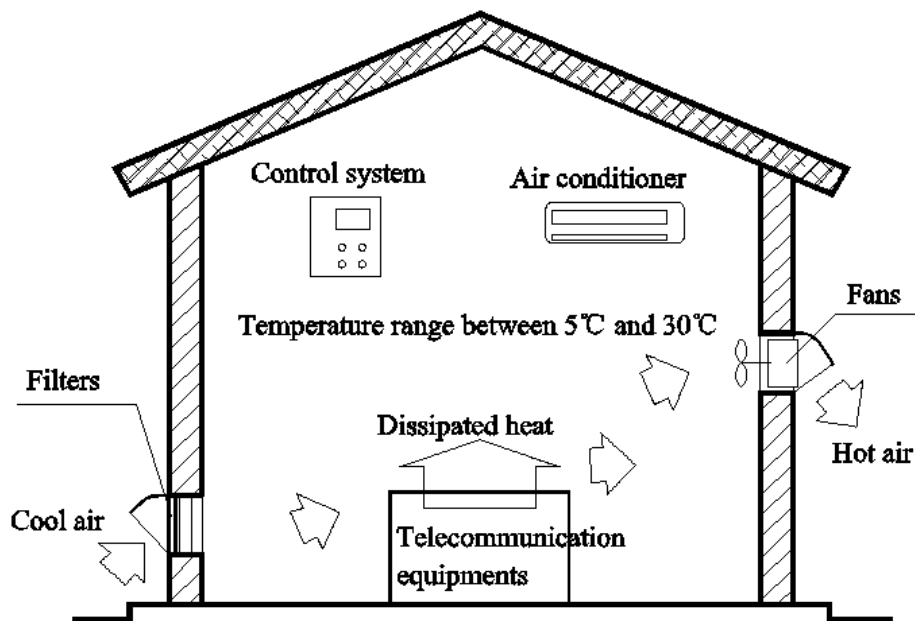


Fig. 16. Schematic drawing of VCT.

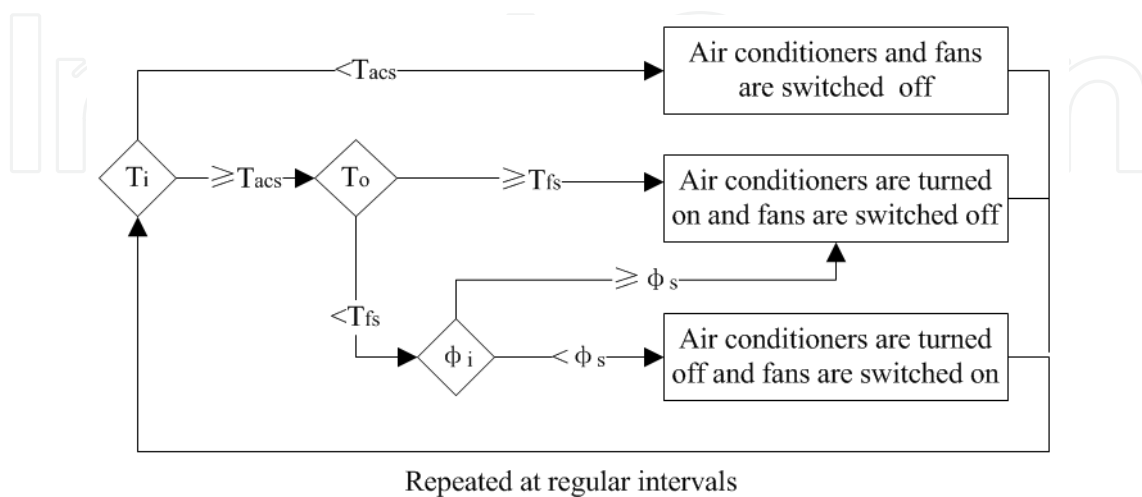


Fig. 17. Control strategy for VCT.

4.1.2 Temperature and humidity environment

The simulation results indicate that the time percentage for an indoor air temperature between 25 °C and 30 °C accounts for 60%, while temperatures between 20 °C and 25 °C account for 20% and those between 5 °C and 20 °C account for 20% (Figure 18). The telecommunication equipment in the typical TBS, called RBS2202, is designed for normal operation in the climatic/mechanical conditions of class 3.1 of ETSI EN 300 019-1-3 (European Telecommunications Standards Institute, 2004). Relative humidity conditions for environmental class 3.1 range from 5% to 85%. The indoor air temperature is much higher than the outdoor air temperature; consequently, the air relative humidity decreases markedly when air is transported into the room. The relative humidity of the air in the TBS is lower than 85% over the majority of the year. The relative humidity set range of air conditioners is from 5% to 85% in the building simulation model, i.e. the room air is humidified when the relative humidity is less than 5% and is dehumidified when the relative humidity exceeds 85%. The simulation results show that there is no need for the room air to be humidified year-round and no need for it to be dehumidified for the vast majority of the year. The dehumidification load is only 6.5 kWh annually. Under the control of the VCT control system, the fans will be turned off and the air conditioners will be switched on automatically to dehumidify the air when the indoor relative humidity exceeds the limit of the range, and consequently the humidity conditions are guaranteed.

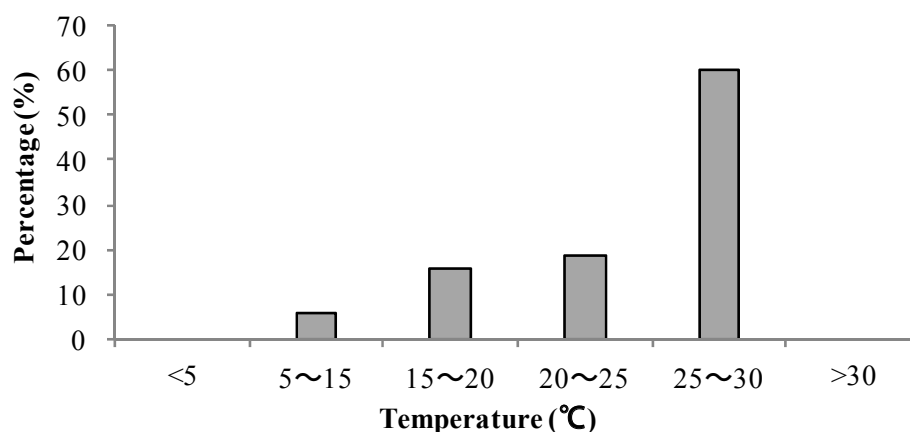


Fig. 18. Time percentage of the indoor air temperature.

4.1.3 Chemically and mechanically active substance conditions

Table 2 shows the atmospheric environment in Guangzhou in recent years and the relative conditions of the chemically and mechanically active substances used in the equipment (European Telecommunications Standards Institute, 2004). The sulphur dioxide and nitrogen oxide content levels meet the acceptable chemically active substance conditions for the equipment. Considering the maximum sedimentation dust content of 8.41 mg/m²h in recent years, filters with filtration efficiency of 85% will be able to maintain an acceptable indoor sedimentation dust content under these conditions. Lower resistance, lower wind pressure loss, ease of maintenance and long cycles for replacement of the filter materials should also be considered during filter selection.

Environmental parameter	Year	Sulphur dioxide	Nitrogen oxides	Dust sedimentation
		(mg/m ³)	(mg/m ³)	(mg/m ² h)
Atmospheric environment in Guangzhou	2001	0.051	0.071	8.41
	2002	0.058	0.068	7.98
	2003	0.059	0.072	8.31
	2004	0.077	0.073	8.21
	2005	0.053	0.068	7.37
	2006	0.054	0.067	7.81
Active substances conditions in equipment		0.3	0.5	1.5

Table 2. Atmospheric environment in Guangzhou in recent years and active substance conditions in equipment.

4.1.4 Condensation risk on the interior surfaces of the building

Water condensation on the interior surfaces of the building envelopes may have negative effects on the telecommunication equipment. Condensation occurs when the interior surface temperature is lower than the air dew-point temperature. The greater the difference there is between the interior surface temperature and the air dew-point temperature, the lower is the possibility of condensation. The air dew-point temperatures were obtained from typical annual meteorological data for Guangzhou and the interior surface temperature was calculated using the building simulation model. Taking the north wall, whose interior surface temperature is the lowest, for analysis, Figure 19 shows that the interior surface temperature is higher than the air dew-point temperature from 1.7 °C to 24.7 °C. Therefore, the condensation risk is quite small.

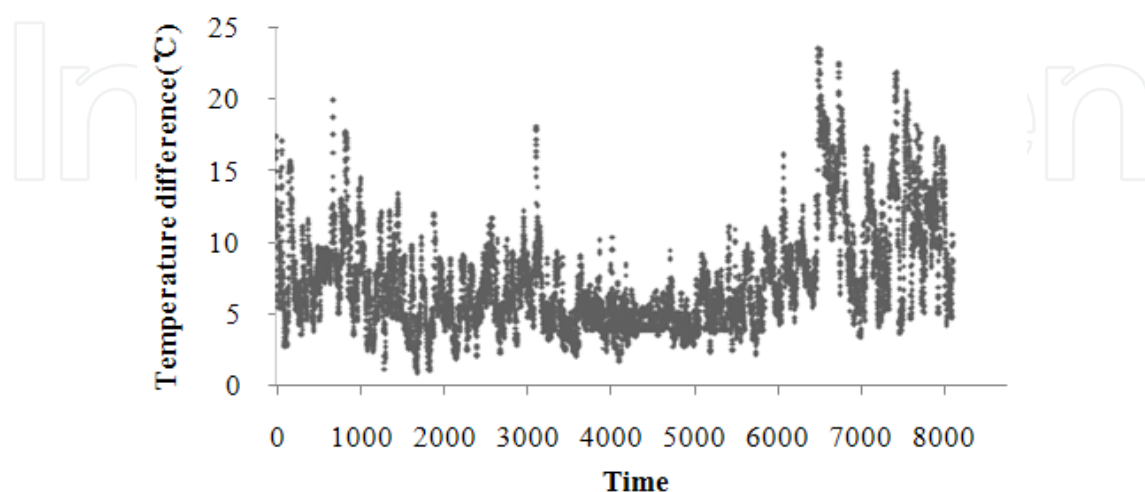


Fig. 19. Difference between the north wall interior surface temperature and the air dew-point temperature.

4.1.5 Cost-effectiveness analysis

The ventilation rate between the outdoor air and the TBS room reaches 50 h^{-1} when fans with total power of 0.22 kW are installed. Because of the high internal heat density, the time when the fans and air conditioners are both turned off is very short. Therefore it can be assumed that the fans run when the air conditioners are switched off (see Figure 13). Table 3 shows that the energy conservation is about 49% for application of VCT to the typical TBS. Additional cost for reconstruction is not more than 5000 RMB, which includes the costs of the fans, filters, ventilation control system and temperature and humidity detectors. Additional maintenance costs for replacing the filter materials are only some hundred RMB annually. The payoff period for the VCT is less than two years, based on a rate of 0.8 Yuan per kilowatt-hour of electricity. The majority of the TBSs in Guangzhou can be reconstructed. Provided that one thousand TBSs are reconstructed and VCT is applied, more than 3 million RMB will be saved annually in electricity bills.

	Typical TBS	Typical TBS using VCT
Annual cooling load of air conditioners (kWh)	31267	11182
Coefficient of performance of air conditioners	3.4	3.4
Power consumption of air conditioners (kWh)	9196	3289
Total power of fans (kW)	0	0.22
Runtime of fans (h)	0	6251
Power consumption of fans (kWh)	0	1375
Total power consumptions (kWh)	9196	4664
Annual Energy conservation (%)	0	49

Table 3. Annual energy conservation of VCT.

4.2 Optimization of airflow organization

The installation location of the fans and openings and the layout of the equipment all influence the temperature and air velocity distribution in the TBS, and therefore influence the heat dissipation of the equipment. Computational fluid dynamics (CFD) simulation provides detailed spatial distributions of the air velocity, air pressure, temperature, contaminant concentration and turbulence by numerically solving the governing conservation equations of fluid flows. It is a reliable tool for the evaluation of thermal environments. A CFD code, PHOENICS, was applied to simulate the temperature and air velocity distributions for the different cases of airflow organization in the typical TBS.

4.2.1 CFD model

Figure 20 shows the model of the typical TBS in PHOENICS created according to the real plan and dimensions of the TBS. The parameters for the simulations were set according to the field investigation results. The simulations were performed under steady state conditions using a k-e turbulent model. A mesh of $0.1\text{ m} \times 0.1\text{ m} \times 0.1\text{ m}$ blocks was used.

The key boundary conditions needed for the calculation comprise:

Openings: External air temperature was set to $22\text{ }^\circ\text{C}$, which is the mean air temperature of Guangzhou according to typical annual meteorological data. External pressure was zero relative to the indoor atmospheric pressure.

Fans: The fan delivery was set according to the ventilation rate of 50 h^{-1} .

Envelopes: The walls, floor and roof were assumed to be adiabatic.

Cabinet model: The cabinet model was created according to the actual cabinet. Each cabinet has two inlets, one outlet and two heat sources. Each heat source was assigned a fixed total heat flux of 271.9 W and the total heat flux for all heat sources in the TBS amounted to 4.35 kW . The wind speed of the outlet was set at the measured value of 1.83 m/s . The actual cabinet and the cabinet model are shown in Figure 21.

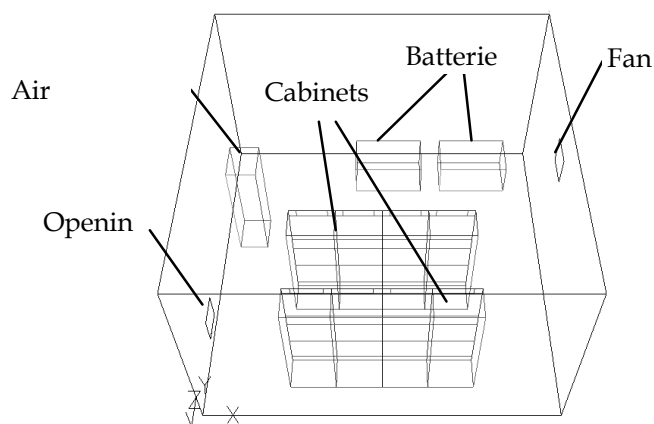


Fig. 20. Model of the typical TBS in PHOENICS.

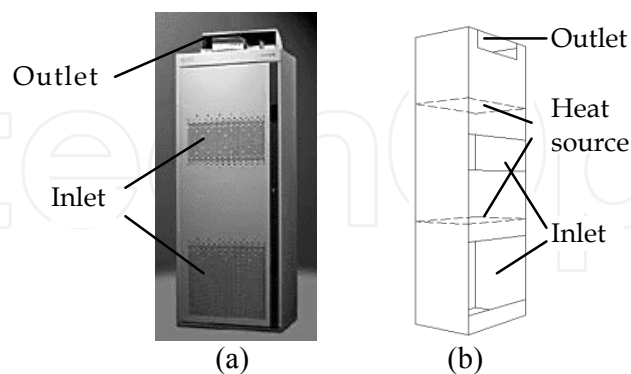


Fig. 21. Actual cabinet (a) and cabinet model (b)

4.2.2 Airflow organization

There are cabinets, batteries, air conditioners, fans and openings in the typical TBS with applied VCT. Taking the convenience of the reconstruction into consideration, the sizes of the openings and the fans should be minimized. The fans and openings are installed on the

exterior walls. The cabinets are relocated for facilitation of the airflow. Several airflow organization cases are proposed as follows:

Case 1: One opening and one fan with dimensions of $0.4\text{ m} \times 0.4\text{ m}$ are installed, where the opening is 0.2 m high and the fan is 1.8 m high.

Case 2: One opening and one fan with dimensions of $0.4\text{ m} \times 0.4\text{ m}$ are installed, where the opening is 1.8 m high and the fan is 0.2 m high.

Case 3: One opening and one fan with dimensions of $0.4\text{ m} \times 0.4\text{ m}$ are installed, where the opening and the fan are both 0.6 m high.

Case 4: Two openings and two fans with dimensions of $0.3\text{ m} \times 0.3\text{ m}$ are installed, where the openings are 0.2 m high and the fans are 1.8 m high.

The total deliveries of the fans in all cases mentioned above were set according to the ventilation rate of 50 h^{-1} . The layout of each case is shown in Figure 22.

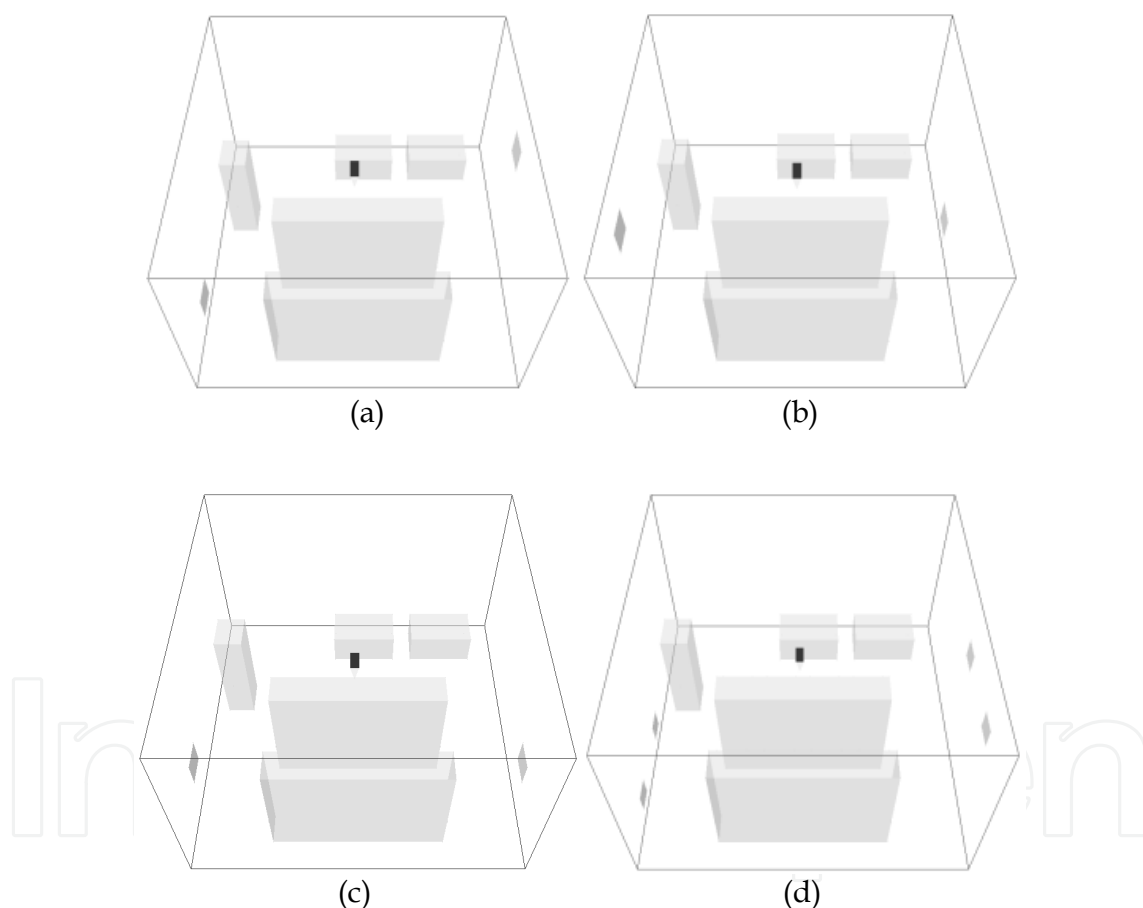


Fig. 22. Layout of each case: (a) Case 1, (b) Case 2, (c) Case 3 and (d) Case 4.

4.2.3 Results and discussion

As cold air is taken into the cabinet through the inlets and dissipated from the outlet, the average temperature of the inlets of all the cabinets for each case is used to evaluate the heat dissipation efficiency. Figure 23 illustrates the contour of indoor temperature of each case at

$z = 0.3$ m. The average temperature of the inlets of each cabinet and of all the cabinets for each case are presented in Figure 24. In Case 2, the cold air is mixed with the hot air exhaust from the cabinets, and the heat dissipation efficiency is greatly reduced. In Case 3, the cool air is quickly dissipated to the outdoors without sufficient heat exchange with the indoor air. In Case 4, due to the additional openings and fans, which are uniformly distributed in the region of the cabinets, the average temperature of the inlets of all cabinets drops by 1.1 °C compared with Case 1. In this study, Case 4 serves as the optimal design.

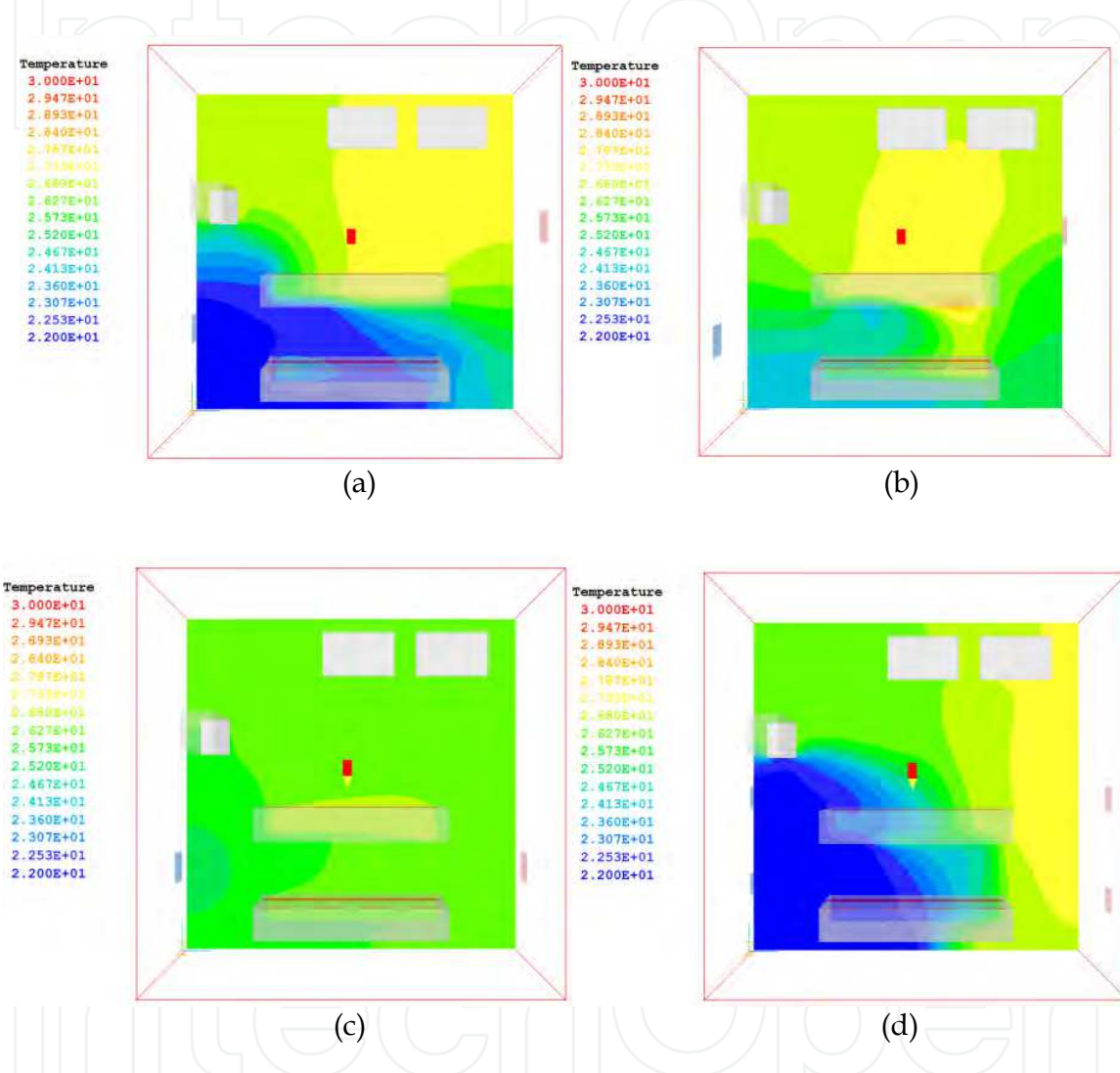


Fig. 23. Contour of indoor temperature (°C) of each case at $z=0.3$ m: (a) Case 1, (b) Case 2, (c) Case 3 and (d) Case 4.

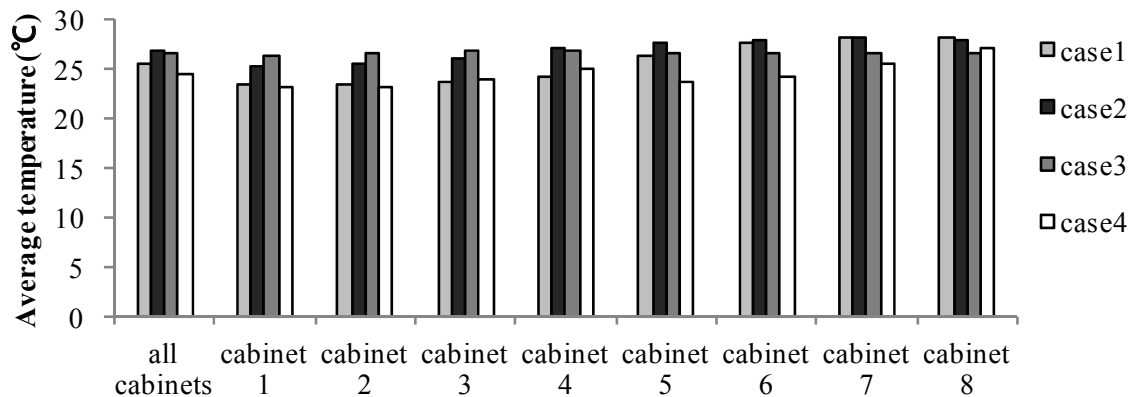


Fig. 24. Average temperature of the inlets of each cabinet and of all cabinets for each case.

Based on the above comparison, the following results are generated:

- 1) The openings should not be set too close to the fans to avoid short circuits.
- 2) The openings should not be set at the height of the outlets of the cabinets, and the fans should not be set at the height of the inlets of the cabinets to avoid mixing of cold and hot air.
- 3) The openings and fans when uniformly distributed in the region of the cabinets can provide a uniform temperature field and better heat dissipation efficiency.
- 4) Results show that optimization of the airflow organization has a strong influence on the heat dissipation efficiency for VCT.

5. Conclusions

TBS buildings have large numbers, high energy consumptions and great potentials on energy conservation. Through field investigation of a typical TBS in Guangzhou, the basic information of TBS was achieved, the key factors influencing energy consumption of TBS were determined and several building energy efficiency designs were proposed. The effect on annual cooling load was analyzed for each building energy efficiency design and the combined effect were achieved for several combinations of the designs by building simulation. The building energy efficiency design strategy for TBS in Guangzhou can be concluded as followings: The indoor air temperature set point of TBS should be elevated to 30 °C regardless of human thermal comfort requirement. Ventilation design is the prior choice for building energy efficiency design of TBS, and other designs are not necessarily considered when ventilation design is applied. For the TBS which is not feasible to apply ventilation design due to practical problems, the combination of designs of high heat transfer coefficient and low solar absorptance walls and roof is strongly recommended.

Study of ventilation cooling technology (VCT) was proposed. The application feasibility of VCT was analysed systematically. The results show that the temperature and humidity requirements of the equipment can be fully met under the linked control of the fans and air conditioners. The chemically and mechanically active substance conditions can be met by using filters with filtration efficiency of 85%. The condensation risk on the interior surfaces of the building envelopes is quite low. The energy conservation achieved by the use of VCT is about 49%, and the payoff period is less than two years. The application of VCT in the TBSs in Guangzhou is feasible, and obvious economic and social benefits will be achieved if VCT can be broadly applied. The PHOENICS CFD code was applied to simulate the

temperature and air velocity distribution for several different airflow organization cases in the typical TBS. The simulation results show that optimization of airflow organization has a strong influence on the efficiency of heat dissipation for VCT.

Acknowledgments

The authors are thankful for the financial support and cooperation of Guangzhou Mobile Communication Corporation. We especially thank the Department of Building Science of the School of Architecture in Tsinghua University for important contributions to the testing.

6. References

- Nakao, M.; Hayama, H. & Uekusa, T. (1988). An efficient cooling system for telecommunication equipment rooms, *Proceedings of the 10th International Telecommunications Energy Conference*, pp. 344-349, San Diego, Canada, October 1988
- Maeda, Y.; Seshimo, Y. & Okazaki, T. (2005). Study of a cooling system for the telecommunication base site, *ASHRAE Transactions*, Vol. 111, No. 2, pp. 746-755, 2005
- Choi, J.; Jeon, J. & Kim, Y. (2007). Cooling performance of a hybrid refrigeration system designed for telecommunication equipment rooms, *Applied Thermal Engineering*, Vol. 27, No. 11-12, pp. 2026-2032, August 2007
- Hayama, H. & Nakao, M. (1989). Air flow systems for telecommunications equipment rooms, *Proceedings of the 11th International Telecommunications Energy Conference*, pp. 1-7, Florence, Italy, October 1989
- Dan, N. & Matti, K. (2000). Application of CFD technique in thermal design of a telecommunication base station, *Proceedings of 9th International Flotherm User Conference*, Orlando, USA, October 2000
- Makhkamdjanov, B.M. (2006). Technological model of the independent power supply with converters of renewable energy for base station of mobile communication, *Proceedings of Internet, 2006 2nd IEEE/IFIP International Conference*, Central Asia, pp. 1-4. Sept. 2006
- Schmidt, R.R. & Shaukatullah, H. (2003). Computer and telecommunications equipment room cooling: a review of literature, *IEEE Transactions on components and packaging technologies*, vol. 26, No. 1, pp. 89-98, March 2003
- Feng, Y. (2004). Thermal design standards for energy efficiency of residential buildings in hot summer/cold winter zones, *Energy and Buildings*, Vol. 36, No. 12, pp. 1309-1312, December 2004
- Athanassios, T.; Andreas, K.A. & Panagiota, K. (2007). Simulation of facade and envelope design options for a new institutional building, *Solar Energy*, Vol. 81, No. 9, pp. 1088-1103, September 2007
- Cheung, C.K.; Fuller, R.J. & Luther, M.B. (2005). Energy-efficient envelope design for high-rise apartments, *Energy and Buildings*, Vol. 37, No. 1, pp. 37-48, January 2005
- Nakao, M.; Ohshima, K. & Jitsukawa, H. (1988). Thermal control wall for telecommunication equipment rooms, *Proceedings of the 10th International Telecommunications Energy Conference*, San Diego, Canada, pp. 280-284, October 1988

- Hong, T.; Zhang, J. & Jiang, Y. (1997). IISABRE: an integrated building simulation environment, *Building and Environment*, Vol. 32, No. 3, pp. 219-224. May 1997
- Bloomfield, D.P. (1994). Final report of IEA Annex 21 (Calculation of Energy and Environmental performance of buildings), *CRC Publications*, London, 1994.
- Zhang, X.; Xie, X.; Yan, D. & Jiang, Y. (2004). Building environment design simulation software DeST (3): validation of dynamic simulation results of building thermal progress, *HV & AC*, Vol. 34, No.9, pp. 37-50, 2004 (in Chinese)
- Yan, D.; Xie, X.; Song, F. & Jiang, Y. (2004). Building environment design simulation software DeST (1): an overview of developments and information of building simulation and DeST, *HV & AC*, Vol. 34, No.7, pp.48-56, 2004 (in Chinese)
- Standardization Institute of Posts and Telecommunications. (1995). *Environmental conditions for telecommunication base rooms*, GF 014-1995, 1995, China (in Chinese)
- European Telecommunications Standards Institute. (2004). *Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; part1-3: classification of environmental conditions; stationary use at weather protected locations*, ETSI EN 300 019-1-3, 650 Route des Lucioles, F-06921 Sophia Antipolis Cedex, France, 2004. [Online]. Available: www.etsi.org.

IntechOpen



Trends in Telecommunications Technologies

Edited by Christos J Bouras

ISBN 978-953-307-072-8

Hard cover, 768 pages

Publisher InTech

Published online 01, March, 2010

Published in print edition March, 2010

The main focus of the book is the advances in telecommunications modeling, policy, and technology. In particular, several chapters of the book deal with low-level network layers and present issues in optical communication technology and optical networks, including the deployment of optical hardware devices and the design of optical network architecture. Wireless networking is also covered, with a focus on WiFi and WiMAX technologies. The book also contains chapters that deal with transport issues, and namely protocols and policies for efficient and guaranteed transmission characteristics while transferring demanding data applications such as video. Finally, the book includes chapters that focus on the delivery of applications through common telecommunication channels such as the earth atmosphere. This book is useful for researchers working in the telecommunications field, in order to read a compact gathering of some of the latest efforts in related areas. It is also useful for educators that wish to get an up-to-date glimpse of telecommunications research and present it in an easily understandable and concise way. It is finally suitable for the engineers and other interested people that would benefit from an overview of ideas, experiments, algorithms and techniques that are presented throughout the book.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Yi Chen, Yufeng Zhang and Qinglin Meng (2010). Building Energy Efficiency Design for Telecommunication Base Stations in Guangzhou, Trends in Telecommunications Technologies, Christos J Bouras (Ed.), ISBN: 978-953-307-072-8, InTech, Available from: <http://www.intechopen.com/books/trends-in-telecommunications-technologies/building-energy-efficiency-design-for-telecommunication-base-stations-in-guangzhou>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2010 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License](#), which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.

IntechOpen

IntechOpen