A

Seminar report

On

HVAC System

Submitted in partial fulfillment of the requirement for the award of degree
Of MCA

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Acknowledgement

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Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Preface

I have made this report file on the topic **HVAC System;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

CONTENTS

INTRODUCTION

Wireless transmission of electromagnetic radiation (communication signals) has become a popular method of transmitting RF signals such as cordless, wireless and cellular telephone signals, paper signals, two way radio signals, video conferencing signals and LAN signals indoors.

Indoor wireless transmission has the advantage that building in which transmission is taking place does not have to be filled with wires or cables that are equipped to carry a multitude of signals. Wires and signals are costly to install and may require expensive upgrades when their capacity is exceeded or when new technologies require different types of wires and cables than those already installed.

Traditional indoor wireless communication systems transmit and receive signals through the use of a network of transmitters, receivers and antennas that are placed through out the interior of a building. Devices must be located such that signals must not be lost or signal strength may not get attenuated. Again a change in the existing architecture also affects the wireless transmission. Another challenge related to installation of wireless networks in buildings is the need to predict the RF propagation and coverage in the presence of complex combinations of shapes and materials in the buildings.

In general, the attenuation in buildings is larger than that in free space, requiring more cells and higher power to obtain wider coverage. Despite of all these, placement of antennas, receivers and antennas in an indoor environment is largely a process of trial and error. Hence there is need for a method and a system

for efficiently transmitting RF and microwave signals indoors without having to install an extensive system of wires and cables inside the buildings.

This paper suggests an alternative method of distributing electromagnetic signals in buildings by the recognition that every building is equipped with an RF wave guide distribution system, the HVAC ducts. The use of HVAC ducts is also amenable to a systematic design procedure but should be significantly less expensive than other approaches since existing infrastructure is used and RF is distributed more efficiently.

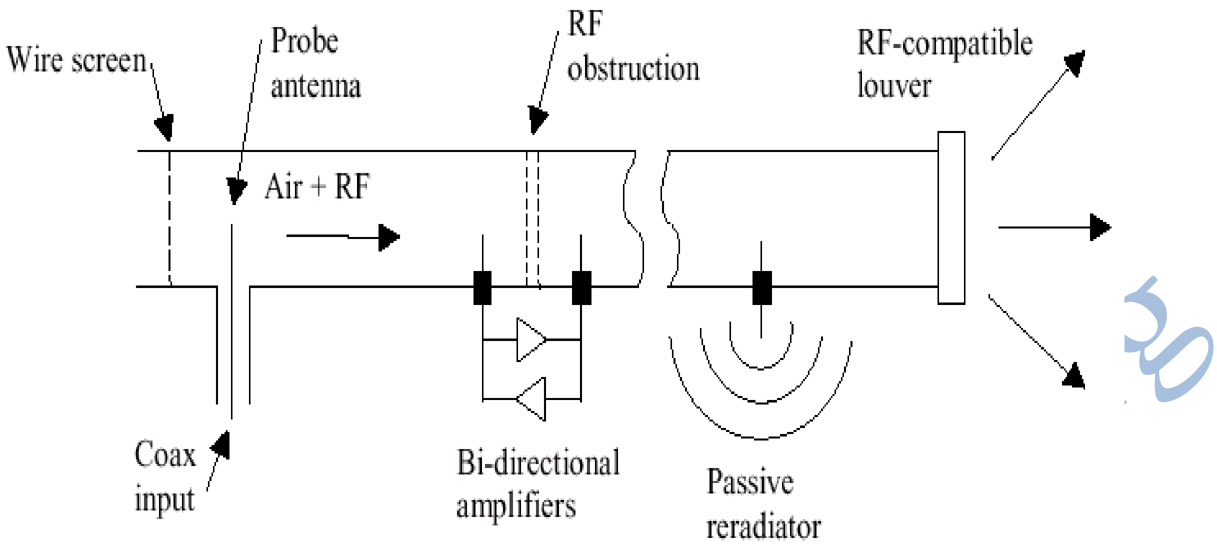
THE HVAC SYSTEM

Heating, Ventilation and Air Conditioning are ducts used in buildings designed to carry air to and from all parts of the building. In most parts of the USA and Europe almost every building is equipped with these HVAC ducts which can also function as hollow wave guides for microwave and RF signals.

Therefore, all forms of wireless transmission can in principle can be done through these waveguides. Since most of the offices and other places in buildings where people work, sit or reside are reached by this HVAC ductwork, it is also possible to provide communications between building occupants and rest of the world.

The HVAC system includes a device usually a coupler for introducing electromagnetic radiation into the duct work such that the duct acts as a wave guide. System also includes devices for enabling the electromagnetic radiation to propagate beyond the duct. In most cases ducts are largest near the central air handling equipment and become smaller as they branch out to various rooms.

Branches in the duct behaves as wave guide power splitters. Eventually RF would be radiated into the rooms through specially designed louvers. Coverage in corridors and spaces guarded from louvers could be realised by placing passive re-radiators in the sides of the ducts.



The key idea behind this distribution is that low loss electromagnetic waves can propagate in hollow metallic pipes if the dimensions of the ducts are sufficiently large compared to the wavelength. Since the HVAC ducts are made of sheet metal, they are excellent waveguide candidates. the lowest frequency that can propagate in a duct depend upon the size and cross section shape of the duct. For rectangular wave-guides or ducts, the cut off frequency f_{co} for the lowest propagating mode is given by

$$F_{co} = \frac{c}{2a}$$

where c = 3x108 m/s, the velocity of light in free space

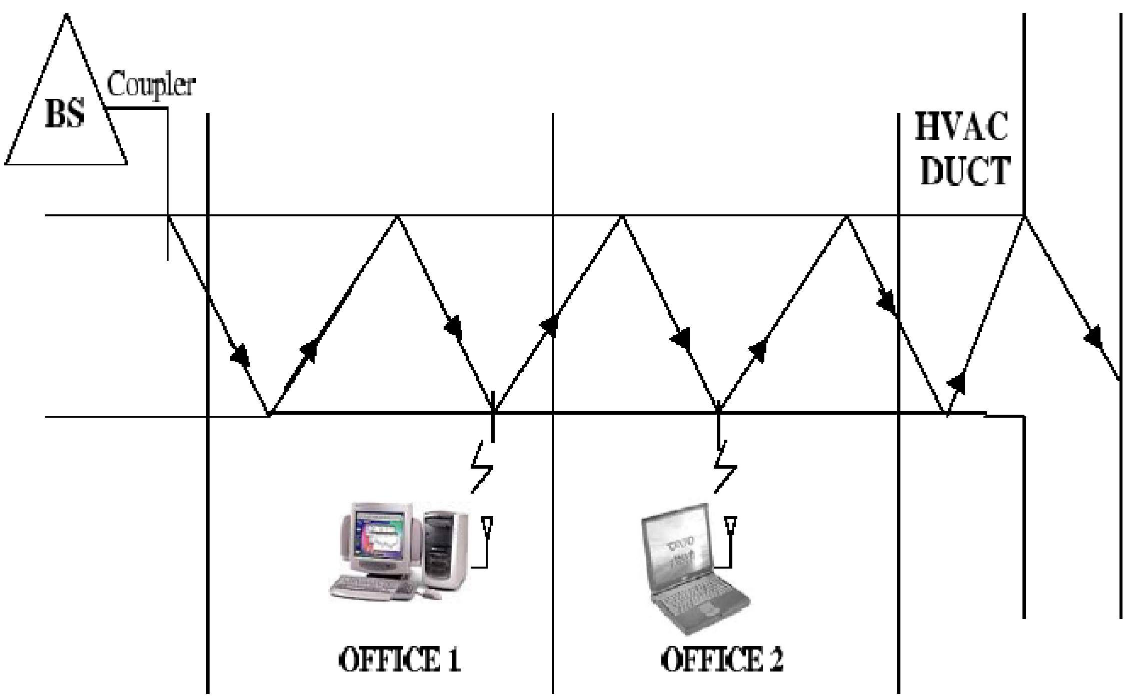
and a = the largest dimension of the duct. For circular ducts,

$$F_{co} = \frac{1.841c}{2\pi r}$$

where r is the radius of the duct. Minimum duct dimensions for several wireless bands are given in the table below.

Band (USA)	Lowest Frequency	Minimum duct width (Rectangular)	Minimum duct radius (Circular)
Cellular	824 MHz	18.2 cm (7.17 in)	10.7 cm (4.20 in)
ISM	902 MHz	16.6 cm (6.55 in)	9.75 cm (3.84 in)
PCS	1.85 GHz	8.1 cm (3.19 in)	4.75 cm (1.87 in)
ISM	2.4 GHz	6.25 cm (2.46 in)	3.66 cm (1.44 in)
U-NII	5.15 GHz	2.91 cm (1.15 in)	1.71 cm (0.67 in)

The basic principle of operation of HVAC system in a building is as shown below

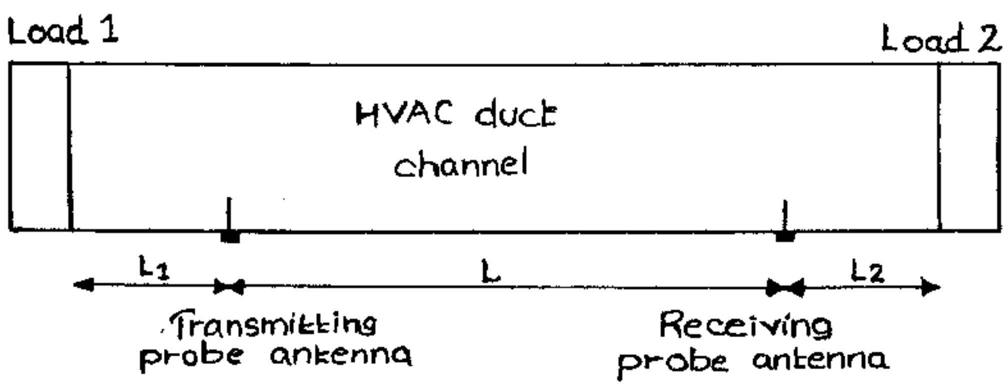


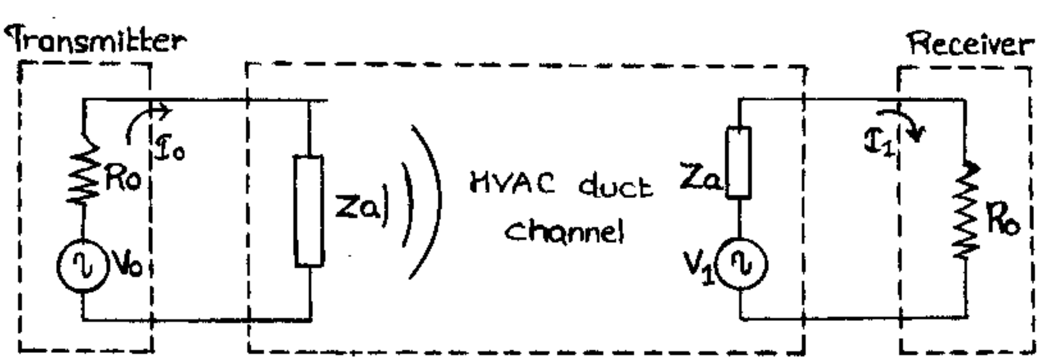
. Basic principle of operation of HVAC system.

The operation is described as follows. For the down link, RF signals sent from a base station propagate through the ductwork and a small portion of electromagnetic energy is radiated by a simple antenna inserted into the HVAC duct passing from each room. In the uplink, the RF signal of the end-user transmitted by the laptop, handset etc. reaches the passive antenna located in each office and propagates towards the base station.

PROPAGATION MODEL

The HVAC channel like all other wave-guides is a linear channel and therefore can be completely characterised by its frequency response or transfer function. To design a wireless HVAC system, an analytic model is necessary. This model must be valid for the ducts of different cross sections and allow investigating easily the frequency response dependence on such parameters as antenna geometry, transmitter receiver separation distance, duct cross section size, conductivity of duct material, reflection coefficients of terminated duct ends etc. Such a model for the HVAC duct channel in the case of a straight multimode duct terminated at both ends is given below.





This is a straight HVAC duct of circular cross-section, made of metal and and terminated at each end as shown. Two monopole probe antennas provide the coupling. Such a duct is a double-probe wave guide with a number of propagating modes N determined by the operating frequency and waveguide dimensions. Let the termination loads 1&2 ie load1 and load2, have respective reflection coefficients '1n & '2n for wave guide of mode n which can be frequency dependent. Let 'L' be the distance between the two antennas and respective distances to the terminated ends be L1 and L2.then theoretically the frequency response can be derived as

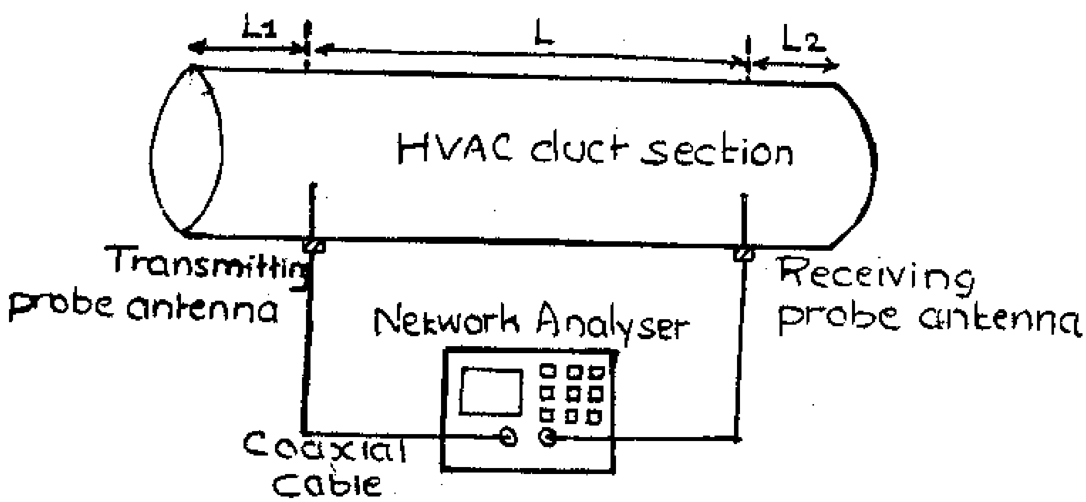
$$|H(f)| = \frac{2R0}{|R0+Za|^2} \left| \sum_{n=1}^{N} Zne^{-\tilde{I}nL} \frac{(1+{}'1ne^{-2\tilde{I}nL1})(1+{}'2ne^{-2\tilde{I}nL2})}{1-{}'1n{}'2ne^{-2\tilde{I}n(L+L1+L2)}} \right|$$

where 'Ro' is the internal impedance of transmitter or receiver; 'Za' the antenna impedence; 'Zn' the impedance due to mode n; '¡n' the propagation constant, ''1n' & ''2n' the reflection coefficients of termination loads load1 and load2.

EXPERIMENTAL VERIFICATION

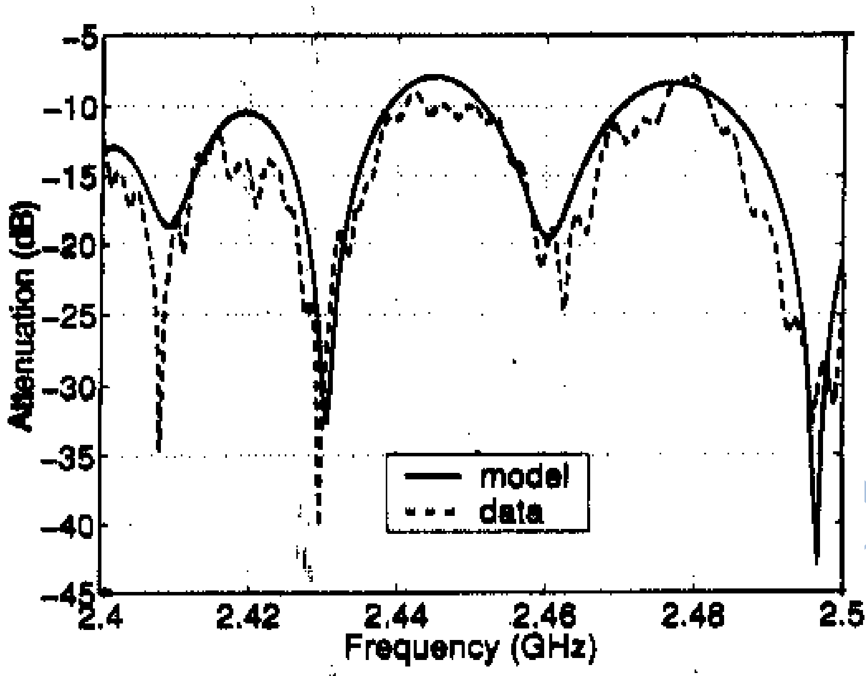
To validate the propagation model already described, verification of the frequency response has to be done experimentally. Measurements were performed on a straight section of a circular HVAC duct 30.5 cm in diameter made of galvanized steel.

The experimental setup is as shown below.



The antennas were thin copper monopole probes 3.5cm long and 1mm in diameter, set on a straight line along the duct length. A network analyzer (Agilent E8358A) with an internal impedance of 50 ohms to measure the frequency response between the probes in the 2.4 to 2.5GHz is used.

The theoretical frequency response was computed for the case of a duct with matched load on both the ends i.e.'= 0. The frequency response shape (number of nulls, their depth and position) depends on the excited mode distribution, the distance between the antennas and the distance between the terminations if any. Three most significant excited modes in this geometry are TE61(R=16.5ohm), TE51(R=8.6ohm), TE41(R=3.5ohm). It is mostly the interference between these three modes that determines the specific locations of peaks and nulls. Adding more modes increases the accuracy of the theoretical curve.



It can be seen that the experimental frequency response curve (dashed line) and the theoretical frequency response curve (solid line) are in good agreement. Small-scale variations observed on the experimental curve are due partially to surface and shape imperfections of the circular HVAC duct used for measurements.

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DISCUSSION

A promising use of the HVAC communication channel is providing high speed network access to the offices in a large building. The HVAC channel is practical and economically viable since it uses an already existing infrastructure.

The capacity of this channel depends on the coherence bandwidth. For frequency response shown, the coherence bandwidth (50% correction) is 11MHz.The coherence bandwidth generally reduces with an increase in transmitter receiver distance due to interference between the multiple propagating modes and their reflections in the duct system.

The optimal transmission scheme under these circumstances is multicarrier modulation. The maximum possible data rate depends on specific coding, modulation, and equalization schemes and can potentially far exceed the maximum achievable data rate over phone lines and power lines, while providing efficient RF distribution for wireless LANs.

RESEARCH ISSUES

Although the preliminary experiments described in this paper support the feasibility of the HVAC RF distribution system, detailed research in a number of areas is needed to develop systematic design procedures. In the following we briefly comment on several of these.

Characterization of the RF channel

Unlike conventional waveguide circuits, in most cases multiple waveguide modes will be above cutoff in ducts. This multimode environment will lead to delay spread much like multi path in open propagation environments. Other sources of delay spread will be reflections from the bends, junctions and end plates. In any event, delay spread and coherence band width of such channel needs to be explored both theoretically and experimentally.

Coupling into multimode ducts

The existence of multiple propagating modes is a complication usually avoided in conventional waveguide circuits. Design and design rules are needed for realizing efficient couplers in the various sizes and shapes of ducts that are commonly used, for each frequency bands of interest.

Mode conversion and cross polarization in multimode ducts

In the presence of multiple propagating modes, it is likely that the preferred strategy is to optimize coupling into the lowest-order, or dominant, wave guide mode. However, since HVAC ducts are not constructed with the same precision as the actual wave guide circuits, mode conversion is likely at joints and other imperfections. In addition to creating delay spread as discussed above, this mode conversion could lead to signal loss owing to excitation to orthogonally-polarized modes, as well.

Power division at branches and tees

To obtain satisfactory power distribution throughout a large building, it will be necessary to be able to determine and control the power division at branches and tees.This power division is also complicated by the 4existance of multiple propagating modes. The use of irises made using wire screens and grids should allow independent control of power division and air flow.

Coupling around obstructions

Techniques are needed to couple around unavoidable obstructions in the ducts. Design for both active and passive coupling needed to be explored. The simplicity of passive probe couplers on either side of the obstruction connected by low loss coax is attractive, but bidirectional amplifiers may be needed in some instances as well. Such technique s could also be used to couple two otherwise unconnected duct systems.

CONCLUSTION

This paper presents a new technique for high speed communication inside buildings which seems to a viable inexpensive alternative to other existing “last mile” technologies. Because existing infrastructure is used and the ducts exhibit losses that are low compared with direct propagation and leaky coax, such a system has the potential to be lower in cost and more efficient than either conventional method.

An approximate, closed-form, propagation model for the straight HVAC duct channel in the form of a multimode wave guide is presented here. Experimental measurements are performed to validate this model and they are found to confirm the theoretical results. Efficient modeling of RF propagation in a real HVAC system is a challenging task. However this model should be perceived as a first step toward predicting the radio coverage in ducts when designing an HVAC wireless distribution system.

REFERENCES

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