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ATTENUATION CONSTANTS AND PHASE CONSTANTS OF THE TUNNELS

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INTRODUCTION

Every one has experienced that radio broadcasting cannot be heard in a tunnel. A communicating system in such a place is a convenience for daily activities, however, in emergencies it may become vital for survival, we can see that great interest is focused on the tunnel and underground's problem. Various authors (Wait and Hill [1][2][3], Delogne [4], Degaugue and Demoulim [5] and Emslie and Lagace [6] have studied tunnel's problemes and recent research in this area has been promising (Murphy and Parkinson [7]). In a disaster, i. e., fires, conventional wire communication systems may become unreliable, necessitating a wireless radio system. This paper prpves that communication by radio wave is fully possible in tunnel. We had been searching for a place where radio wave noises were minimal or nonexistant in order to perform experimental studies. The inside of a long tunnel seemed to fulfill the necessary requirements. However, during the experiments, it was discovered that the tunnel itself was a transmission line of high pass type [8], similar to the circular waveguide.

The three main purposes for the present study were, first, to experimental prove the possibilities of radio communication in the tunnel, second, to obtain attenuation constant and thired, to obtain phase constant, theoretically and experimentally.

Communication Experiment

A straight 1470 meter long tunnel constructed of concret was employed [Fig. 1 (a)]. The transmitter and receiver, a wireless telephone commonly found in taxicab radios, was used at frequency of 470 MHz with a transmitting strength of 0.5 watt. Experimental communications under the above-mentioned conditions as well as when the antenna of the fixed station was moved into the tunnel proved that communication was as audible as public telephone. Although the distance between the transmitting and receiving antenna is varied, large variations in communication could not be found, hence, it is conceivable that even in a longer tunnel complete communication is possible.

Determination of Attenuation Constant

A fixed station and antenna were set 30 meters outside the entrance of the tunnel and the radio wave sent into the tunnel. The mobile station and an antenna were placed on a track and moved along the tunnel during the experiment [Fig. 1 (a)]. The output of field strength measurement is continuously recorded by a pen written recorder. In this manner, the variation of field strength against the distance in the tunnel was found and immediately the attenuation constant was determined. The attenuation constant is shown in Fig. 1 (b). As a result of investigating many data of concrete tunnels (when operating far from cutoff [8]), the attenuation constant α is related to λ and a as follows:

$$\alpha = 1460 \; (\lambda^2/a^3) \qquad [\text{dB} / \text{km}]$$

where λ: free space wavelength of the wave, a: radius of the tunnel.

Determination of Wavelength in the Tunnel

The experimental arrangement used is shown in Fig. 2 (a). Screen reflector acts as a short plate. A fixed station and antenna were set inside the tunnel and the radio wave sent towards the screen reflector. The receiver and receiving antenna were placed on a lorry and moved along the rail during the experiment and the output of receiver is continuously recorded by a pen written recorder. In this manner, the standing wave in the tunnel was found and immediately the wavelength in the tunnel was determined [Fig. 2 (c)]. Wavelength increases with decreasing frequency. The problem involving modified cross section [Fig. 2 (b)] can be solved by means of Rayleigh-Ritz's method [9], on the assumption of perfect conducting wall. The results for the lowest order TE_{01} and TE_{11} mode are shown in Fig. 1 (b). The experimental values agree well the theoretical results. The lowest cutoff frequency (TE_{11} mode) is 23.5 MHz.

CONCLUSIONS

By this study:

1. It was proved that radio communication using the tunnel was fully possible.
2. Propagation constant of the tunnel could be obtained.
3. If the diameter of the tunnel is from several times to ten

times longer than transmitting wavelength in free space, the tunnel can be used as a transmission line of wave.

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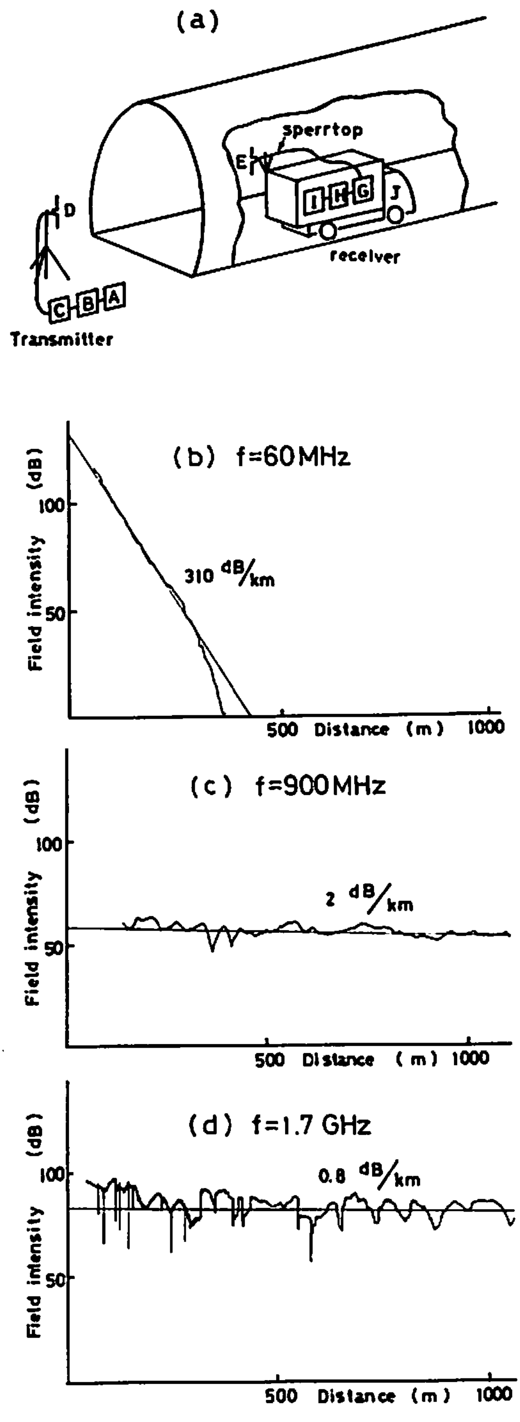

Fig. 1
Attenuation constant.

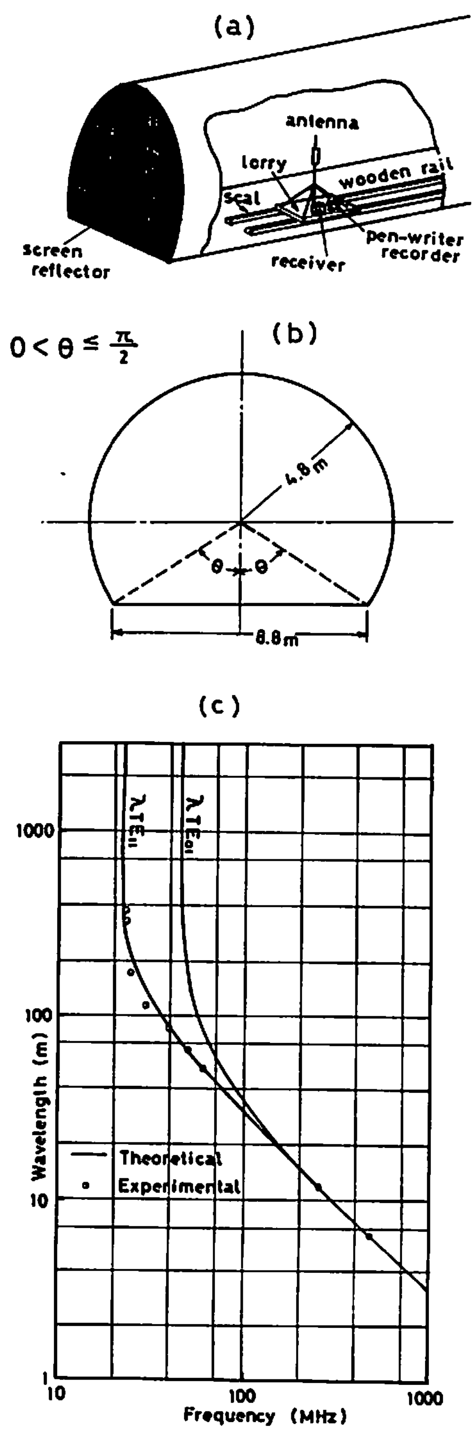

Fig. 2
Wavelength in the tunnel.