Investigation of VHF signals in bands I and II in southern India and model comparisons

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In order to achieve a highly reliable communication with a simple and small receiver, one requires the knowledge of the spatial and temporal variability of field strength. This assumes greater significance in broadcasting applications where the user expects a very high quality signal. The performance of any communication circuit depends on the models employed to calculate the coverage area and interference problems. The development and identification of models is a continuing and ongoing process and there is always scope for refinement. With this objective some field strength measurements were conducted using Chennai TV and FM stations in several radials. The variability of the path loss as a function of distance has been studied and path loss exponents deduced from the observed values were compared with the model available in literature. The agreement and deviations of the model with the observed results are presented and discussed and two approaches have been proposed to compare the observed results.

Keywords: VHF signal, Communication circuit, Pathloss, Field strength.

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1 Introduction

In the past, especially in the late eighties and early nineties when national TV network was in its peak expansive phase, the communication group at National Physical Laboratory (NPL), New Delhi, initiated many studies on the understanding of propagation mechanisms of TV signals from coverage and interference points of view. This had been carried out using different available TV signals. The NPL communication group collaborated with many other groups in India to collect and enhance data and the results have been published in different contexts1-6. The tropical troposphere with its steep humidity gradients and strong temperature inversions contributed to severe interference among VHF users over this country. There are many users in this band apart from broadcasting applications. Continuous upgrade of signal strength prediction procedures and simplification of link design procedures can lead to optimization of performance estimations, minimization of interference problems and efficient functioning of communication circuits.

2 Experimental details

Keeping the above objective in view, in the present study, investigations of attenuation of VHF signals in band I and band II using Chennai TV and FM stations have been carried out using Rohde and Schwarz portable battery-operated field strength meter. The objective was to estimate the coverage of these two transmitters. This gives an idea of satisfactory reception of FM and TV signals in the cities where survey was conducted. In the case of TV, the video carrier was monitored at 62.25 MHz and FM was monitored at 107.1 MHz. The survey was conducted in seven radial directions from these transmitters. The measurements were conducted mostly in the evening hours to early hours of the night. The radials are:

(i) Chennai-Nellore (Andhra Pradesh) with a maximum distance of 146 km
(ii) Chennai-Tirupati (Andhra Pradesh) with a maximum distance of 112 km
(iii) Chennai-Chittoor (Andhra Pradesh) with a maximum distance of 129 km
(iv) Chennai-Vellore (Tamil Nadu) with a maximum distance of 125 km
(v) Chennai-Tiruvannamalai (Tamil Nadu) with a maximum distance of 164 km
(vi) Chennai-Villupuram (Tamil Nadu) with a maximum distance of 155 km
(vii) Chennai-Mahabalipuram (Tamil Nadu) with a maximum distance of 155 km.
The Chennai TV operates at 62.25 MHz and Chennai FM operates at 107.1 MHz. The transmitting powers of the stations are 53.7 and 14.12 kW (e.r.p.). Both the transmitting antennas are situated at a height of 130 m and 150 m, respectively. Both the receiving antennas are situated at a height of 10 m. The field strength values measured at a given distance are averaged out into a single value and converted into a path loss value [using the equation, Path loss = (Transmitting power + Transmitting antenna gain + Receiving antenna gain – Received power)]. This value is called observed path loss from now onwards.

3 Results

Figure 1 depicts the variation of these path losses as a function of distance for all the seven radials for the Chennai TV signal. The striking feature of this figure is the range bound path losses for all the radials at all distances. For all the radials up to a distance of 40 km the path loss values lie in a very narrow range. Beyond 40 km, path loss values lie in a range of 30 dB depicting the same type of variation. At distances close to the transmitter, the variation of path loss between the radials is 2 dB and increases to 10 dB at 40 km distance. This shows that propagation mechanism is same in all directions, and local terrain features have no effect on the signal strength values. The corresponding free space variation is also shown in Fig. 1. The LOS distance in the case of TV comes to 44 km and in the case of FM it is around 45 km. Beyond this, both the signals might have undergone the change in propagation mechanism from LOS to diffraction.

Figure 2 shows the same variation of observed path losses as a function of distance for Chennai FM station. The general trend in both the Figs 1 and 2 is same. Here at 10 km distance, path losses are confined to around 85 dB and at 40 km distance the path loss increases to 115 dB. In Fig. 2 the variation of path loss for different radials is less compared to Fig. 1. At 40 km distance, path losses vary by 10 dB, whereas in Fig. 1 the corresponding variation is 20 dB. Here variation of path losses for different radials beyond 100 km is high, going up to 35 dB. The free space variation is also shown in Fig. 2.

The observed path loss values are converted into path loss exponents using the procedure outlined as follows. These are compared with the values deduced from model following the approach of Perez-Vega and Zamanillo.

4 Path loss model

The observed signal strength values are converted into path loss values using the received power, transmitted power and gains of the transmitting and receiving antennae. These are designated as observed path loss values. The path loss exponents from the observed path losses are deduced as follows.

![Graph](image)
$L = L_0 + 10 n \log_{10} (d)$ \hspace{1cm} \ldots (1)$

where $L$ and $L_0$ are the path losses at distances $d$ and 1 metre, respectively.

$L_0 = 20 \log_{10} \left( \frac{4\pi d}{\lambda} \right)$ \hspace{1cm} \ldots (2)$

or, in logarithmic units it is given by

$L_0 = 32.45 + 20 \log f_{\text{MHz}} + 20 \log d_{\text{km}} \hspace{1cm} \ldots (3)$

By substituting $d = 1$ m, we can get the free space loss at 1 m from Eq. (2). Using Eqs (1) and (2) ‘$n$’ can be deduced from the experimental data. The exponent thus deduced is called observed exponent value.

4.1 Prediction model

Based on the Federal Communication Commission (FCC) curves, Perez-Vega and Zamanillo developed a computational path loss model. The path loss exponent is characterized as a function of distance and transmitting antenna height. This can be further used to deduce median path loss, field strength, etc. The model is based on a receiving antenna height of 9 m. In the present study, observed path losses have been normalized from their original receiving antenna height of 10 m to the receiving antenna height of 9 m, so that the path loss exponents deduced from this can be directly compared with the model predicted values. According to their model, $n$ is given by

$n = \sum_{i=0}^{4} \sum_{j=0}^{4} a_{ij} h^i d^j \hspace{1cm} \ldots (4)$

where $h$ is the height of transmitting antenna in metres and $d$ is the distance in km. The values of the coefficients for SI units are taken from the model of Perez-Vega and Zamanillo. The advantage of this model is: it is independent of propagation mechanism, terrain, meteorological data, etc. It has been developed by using Eq. (4) and fitting the coefficients for FCC data base of VHF and UHF circuits. Especially if found suitable in Indian zones this becomes very handy in designing FM and TV and other communication circuits. The method is easy to compute and independent of frequency. Hence, it is wise to apply to these bands only. The present workers have carried out a lot of studies in the VHF and UHF bands and the propagation mechanisms have been used to deduce the path losses with the help of meteorological data sets. In the present method, such data sets for computations are not necessary.
5 Discussion

Based on the aforesaid formulations, path loss exponents deduced from the model and observed data for the Chennai TV and FM are shown in the Figs 3 and 4. The model values are obtained by using the transmitting antenna heights for the corresponding path and various distances. A software has been developed to compute path loss exponent from the Perez-Vega and Zamanillo model. Figure 3 shows the variation of exponent as a function of distance for Chennai TV for all the radials along with the model values. Here the observed and model values are plotted from 2 to 146 km. Up to a distance of 60 km, predicted values give excellent agreement with the observed values. After a distance of 50 km, slight deviation is seen. Beyond 50 km, propagation mechanism might have been changed from line-of-sight to diffraction or scattering. In Fig. 3, trend of observed values is more or less the same. The observed values of $n$ lie between 2.1 and 2.9 and the model shows good agreement with the observed values up to 60 km distance and thereafter the deviation increases. At 110 km distance, model predicts a value of 3.0, whereas the observed values lie between 2.4 and 2.9. Overall radial 4 gives better agreement with the model values and radial 5 exhibits lowest values as compared to other radials and shows the maximum deviation from the model. Agreement is not good between 60 and 120 km, and beyond 120 km good agreement is seen. In this range, observed values lie between 2.3 and 2.8 and the model shows the values between 2.8 and 3.0.

Figure 4 depicts the variation of path loss exponents for Chennai FM station along with model values for all the radials. In Fig. 4 observed and model values are plotted up to 158 km. At 100 km distance, observed values depict an exponent of 2.1-2.5, whereas the model shows a value of 2.9. Here the deviation increases from 40 km and large deviations are seen between 60 and 120 km. In the case of FM, the deviations of the model are slightly higher as compared to TV signals. In fact, the model of path loss exponents overestimates the observed values. In both the Figs 3 and 4, most of the radials get intermixed and depict the same average values. This shows that, in a given environment, in any direction from transmitter path loss exponents should lie in a given range denoting the same propagation mechanism up to certain distances and then changing into another. After examining the deviations from Perez-Vega and Zamanillo model an attempt is made to compare the observed values of path losses from the following equations.

\[ L_1 = 32.45 + 20 \log_{10} f_{MHz} + 10(n + 2) \log_{10} d_{km} \]  

Fig. 3 — Comparison of observed and Perez-Vega and Zamanillo model deduced exponents for Chennai TV.
Here, $L$ has been calculated by using the observed values of exponents for each radials separately for both TV and FM, and the predicted losses from Eq. (5) have been compared with the observed values of path losses for Chennai TV and FM. The comparison is shown in Figs 5 and 6 for TV and FM, where the predicted values are denoted by the word “proposed 1” for different radials. In Fig. 5, at a distance of 20 km, observed losses lie between 105 and 115 dB and the proposed 1 model values are around 120 dB. At 60 km distance, the corresponding values are between 115 and 130 dB for observed values and predicted values are around 140 dB. At all distances, deviation is remaining between 10 and 15 dB. In the case of Fig. 6 for Chennai FM, the deviation at various distances varied from 15 to 25 dB. It appears that the deviation in the case of FM signals is higher as compared to TV signals. A perusal of Figs 5 and 6 indicates that the observed losses for all the radials in FM case are more range-bound than in the case of TV signals. In the case of FM signals, the variation of observed path loss among all the radials is around 10 dB, whereas in the case of TV signals it is around 20 dB.

After examining the above deviations, it was thought that the distance dependence term in Eq. (4) can be changed in to $10^n$ instead of $10^{(n+2)}$ in the following form.

$$L_2 = 32.45 + 20 \log f_{\text{MHz}} + 10 \log d_{\text{km}} \quad \ldots(6)$$

The losses calculated from Eq. (6) are denoted as “proposed model 2”. Again the observed losses for all the radials have been compared with the proposed model 2 values for Chennai TV and FM. These are shown in Figs 7 and 8. In Fig. 7, at 20 km distance, predicted loss varied between 95 and 100 dB among all the radials and the observed loss varied between 105 and 115 dB. At 60 km distance, the corresponding variations in loss are 107-115 dB for predicted and 120-140 for observed ones. At 100 km distance, the variations are between 110 and 120 and between 130 and 145 dB, respectively. It seems the proposed model 2 underestimates the observed losses. In Fig. 8 also, similar trend is seen. At 20 km distance, predicted ones are in the range of 95-100 dB and observed ones are between 105 and 115 dB.

At 60 km distance, the variations are between 105 and 115 and between 120 and 140, respectively. At a distance of 100 km, the loss varied between 110 and 122 and between 130 and 140, respectively. Overall, it appears that proposed model 2 underestimated the observed loss by 15 dB at 20 km, by 10-20 dB at 60 km and by 20-25 dB at 100 km for TV measurements. For FM measurements the model underestimated the observed loss by 10-15 dB at 20 km, by 15-25 dB at 60 km and by 20 dB at 100 km distances.
Fig. 5 — Comparison of observed and proposed model 1 deduced exponents for Chennai TV

Fig. 6 — Comparison of observed and proposed model 1 deduced exponents for Chennai FM
Fig. 7 — Comparison of observed and proposed model 2 deduced exponents for Chennai TV

Fig. 8 — Comparison of observed and proposed model 2 deduced exponents for Chennai FM
Some height gain measurements for DTV reception in Singapore were reported by Ong et al. They concluded that height gain is a function of local environment surrounding the mobile unit as well as the ground reflection and radiation pattern of the transmitting antenna. Since there was no prediction of path loss exponent and comparison of observed values with the models, present results cannot be compared with their results. In the VHF and UHF bands Chung and Bertoni proposed a theoretical model for predicting the average path loss from an elevated base station to subscriber antennas at rooftop level, mainly, in the urban residential areas. They have generalized the approach of Walfish and Bertoni’s theoretical model for UHF urban propagation and cannot be applied in the present study, where measurements are conducted only for small distances in the urban zone and proceeded towards suburban and open areas. Also this model does not talk about the modelling of path loss exponent which is the subject matter of this study.

6 Summary and conclusions
Here the experimental data collected in a RF survey from Chennai TV and FM stations in seven radial directions have been utilized to deduce path loss exponents and these have been utilized to compare the exponents deduced from the model of Perez-Vega and Zamanillo. The comparison showed that agreement is good up to distances of 40-50 km from transmitter and thereafter there is deviation of the model from the observed values. The observed ones are also compared with two proposed models. Proposed 1 model overestimated the losses and TV measurements showed better agreement with the predicted ones than FM measurements. Proposed model 2 underestimated the losses in the case of both TV and FM measurements and the deviations in both the cases are more or less the same. In regions where observed results are available, one can convert these into exponents and apply for predicting losses in similar climatic regions. In places where no measurements are there, for first hand approximation, one can use Pervez-Vega and Zamanillo model for estimating path losses. This is a preliminary study in this direction and we are planning to compare Pervez-Vega and Zamanillo model with various data sets collected from different regions of India and validate this model.

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