Estimating Tropospheric Ducting Effects from Received Signal Quality of Digital TV Services

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Abstract - **This paper reports on the methodology of estimating tropospheric ducting effects from the received signal quality of terrestrial digital TV services. The results are correlated with the variation of the modified refractivity of the atmosphere as a function of height, clearly indicating the formation of the tropospheric ducts at the time of the measurement. Prediction of the received signal enhanced by the tropospheric ducting using ITU-R P.1546-5 shows good match with the measurement.**

Index Terms — **Tropospheric ducting, ITU-R P.1546**

1. Introduction

For many decades the planning of high power terrestrial television (TV) services in the Newcastle, Sydney and Illawarra service areas in the state of New South Wales, Australia has had to take into account the impact of co-channel interference. The co-channel interference is understood to be caused by the tropospheric ducting significantly reducing the path loss of the interfering signal. The tropospheric ducting is associated with abnormal vertical distribution of the refractive index [1]. Since 2003 investigation has been undertaken into measures toward mitigation of interference from Illawarra services into the Hunter region.

Conventionally, the effects of tropospheric ducting were observed by directly measuring the signal strength enhanced by the tropospheric ducting (e.g. [2]). Such method typically requires an exclusive use of the frequency and setting up of a new measurement equipment. In a region where existing terrestrial digital TV broadcasting services are known to suffer from co-channel interference due to the tropospheric ducting, the signal strength of the interference signal may be estimated from the received digital TV signal quality, in particular from the modulation error ratio (MER) [3]. The proposed method is expected to allow the estimation of the signal level enhanced by the tropospheric ducting for a small percentage of time by utilizing a commercially available digital TV signal analyzer and existing digital TV broadcasting services.

2. Estimation of Interference Signal Level

MER, R_M, is defined as [3]

$$R_M = \frac{\sum_{j=1}^{N_M}\left(I_j^2+Q_j^2\right)}{\sum_{j=1}^{N_M}\left(\delta I_j^2+\delta Q_j^2\right)} \quad (1)$$

where I_j and Q_j are ideal co-ordinates of the jth symbol constellation, δI_j and δQ_j are the errors in the jth received co-ordinates. N_M is the number of data points in the measurement samples.

Assuming that the wanted signal, interference signal, and noise are all uncorrelated, the measured signal level can be expressed as the following:

$$P_C = P_W + P_I + P_N \text{ [mW]} \quad (2)$$

where P_C, P_W, P_I, and P_N are measured signal level, wanted signal level, interference signal level, and noise level, respectively.

Provided that the interference signal would appear as a Gaussian noise to the receiver of the wanted signal, and the degradation of the symbol constellation would depend solely on the power ratio of the wanted signal over interference plus noise level, the MER can be expressed as follows:

$$R_M = \frac{P_W}{P_I+P_N} = \frac{P_C}{P_I+P_N} - 1 \quad (3)$$

Rearranging the above equation, the interference signal level plus noise is given by

$$P_I + P_N = \frac{P_C}{R_M+1} \text{ [mW]} \quad (4)$$

3. Modified Refractivity

The modified refractivity, *M*, is useful in identifying the formation of tropospheric ducting. It is given by [4]

$$M = N + 150h \quad (5)$$

where *h* (km) is the height. The radio refractivity, *N*, can be approximated as [4]

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) \quad (6)$$

where *P*, *T*, and *e* are total atmospheric pressure (hPa), absolute temperature (K), and water vapor pressure (hPa).

4. Measurement

The digital TV signal quality measurement was performed at Medowie, measuring MER of the wanted signal from Mt Sugarloaf, being interfered with by the signal from Illawarra, all in New South Wales, Australia, at 585.5 MHz.

The parameters of the two transmitters are as follows:

- Mt Sugarloaf (Wanted signal)
  - Latitude: 32°53'30.00"S
  - Longitude: 151°32'15.00"E

- Antenna height (asl): 553 m
- ERP towards Medowie: 223 kW (85.6 dBm)
- Path length: 36.6 km.
- Illawarra (Interference signal)
  - Latitude: 34°37'14.00"S
  - Longitude: 150°41'44.00"E
  - Antenna height (asl): 927 m
  - ERP towards Medowie: 243 kW (86.0 dBm)
  - Path length: 236 km.

For the receiving site, Hills SFX91B4 Yagi antenna was installed at the height of 5 m from the ground, pointing towards Illawarra Tx. The antenna gain minus cable loss was estimated to be 12 dB. Pixelmetrix's DVStation-Mini3 DVB-T analyzer was used to measure the received signal level and MER.

For the present analysis, the measurement data from the 1st of January 2014 to the 1st of January 2015 was analyzed. Measurement samples were obtained approximately every 5 minutes. Not all data were available due to device malfunctioning. In total, measurement data was available for 95.7% of the time. We note that the remaining 4.3% of the time falls into the summer in Australia, where we expect that the occurrence of tropospheric ducting is more frequent compared to the winter time. Hence the end result may be slightly biased towards less interference.

The radiosonde measurement by the Bureau of Meteorology was conducted at Williamtown, 8.5 km from the Medowie Rx site towards the Illawarra Tx. The climate parameters required to derive the modified refractivity were obtained from the radiosonde measurement.

Figure 1 shows an example of weekly variation of estimated interference plus noise level, compared with the modified refractivity derived from the daily radiosonde measurement. The formation of the tropospheric ducting is indicated by the shift of the vertical variation of the modified refractivity. It can be seen that the formation of the tropospheric duct and the enhancement of the interference signal are correlated.

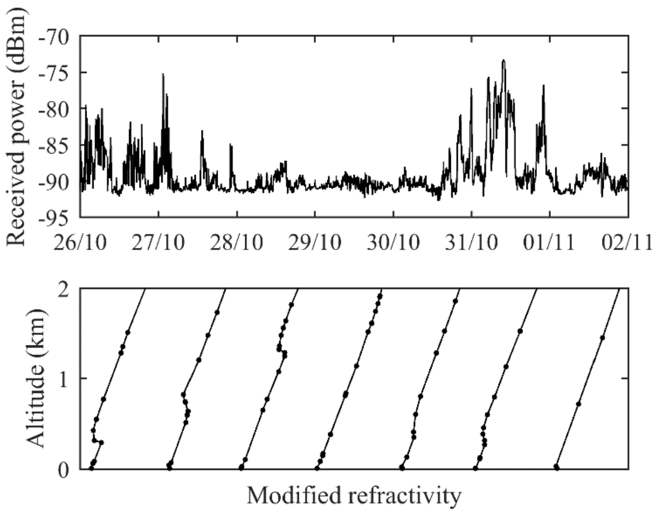

Fig. 1. Estimated interference plus noise level compared with measured modified refractivity.

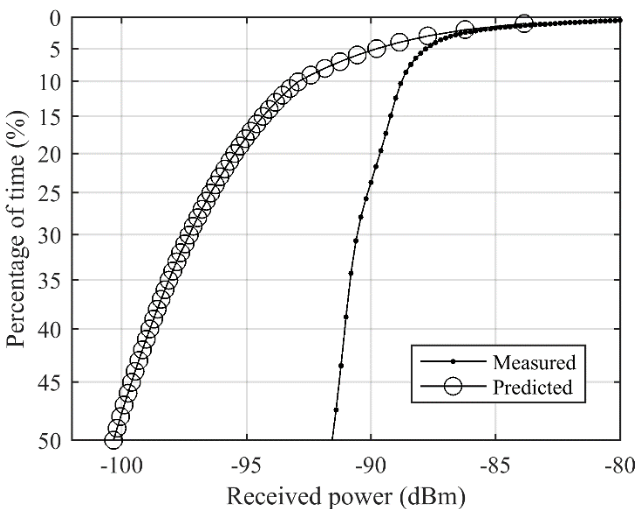

Fig. 2. Time variability of interference signal estimated from measurement and predicted by ITU-R P.1546-5.

5. ITU-R P.1546-5 Prediction

The parameters used for the prediction of the received interference signal at Medowie Rx from the Illawarra Tx by using the ITU-R P.1546-5 are as follows:

- Operating frequency f: 585.5 MHz.
- Horizontal path length d : 236 km.
- Transmitting/base antenna height h_1: 858 m.
- Representative clutter height : 10 m.
- Terrain clearance angle correction : 0 dB.
- Slope path correction : 0 dB.
- Receiving/mobile antenna height correction : -6dB.

Figure 2 shows the time variability of the interference signal estimated from the measurement and predicted by ITU-R P.1546-5. It can be seen that the prediction and the estimation from the measurement match well at 1 to 2% of the time. Beyond 3% of the time, the effect of noise dominates the statistics of the measurement results, indicated that the proposed method is applicable only for the small percentage of the time.

6. Conclusion

This paper presents a methodology of estimating the effects of tropospheric ducting from the received signal quality of digital TV broadcasting services. Simplification was made in assuming that the MER degradation was solely depending on the difference in wanted and interference signal levels, neglecting such effects as frequency selective fading. A further study is expected to follow.

References

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