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DETERMINATION OF THE TIME DELAY IN THE CASE OF TWO-PATH PROPAGATION ON THE BASIS OF THE ATTENTUATION CHARACTERISTICS FOR TWO ADJACENT FREQUENCIES

H. G. Gilroi

Translation of "Bestimmung der Laufzeitdifferenz bei Zweiwegausbreitung aus dem Daempfungsverlauf fuer benachbarte Frequenzen," Kleinheubacher Berichte, Vol. 19, 1976, pp. 261 - 265

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16. Abstract

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DETERMINATION OF THE TIME DELAY IN THE CASE OF TWO-PATH PROPAGATION ON THE BASIS OF THE ATTENUATION CHARACTERISTICS FOR TWO ADJACENT FREQUENCIES

H. G. Gilroi*

ABSTRACT. Pronounced fading occurring in the line of sight radio links at frequencies below 10 GHz can be traced to the effects of multipath propagation. Modulation disturbances depend on travel time differences between the direct wave and the wave which is reflected at atmospheric layers. A method described for the determination of the time delay is based on an indirect approach which utilizes the difference in fading at various frequencies. The method was employed in measurements involving a distance of 181 km. The results obtained in the measurement are discussed.

1. Multipath fading

Pronounced fading in line of sight radio links is attributed /261 in the case of frequencies below 10 GHz to multipath propagation. Transmission factor and transmission angle depend on the frequency when the direct wave and the waves reflected on atmospheric layers interfere. In the broad frequency bands of the multichannel radio

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link, level fluctuations and intermodulation noise occur in the modulated signal. According to the two-path model, these modulation disorders depend on the time delay τ between direct and reflected wave.

2. Method for determination of the time delay

The time delays here are too short to be measured directly for the available band width as the distance between a pulse and its echo. Only indirect methods are applicable. In the following studies, the different fading for different frequencies is used.

For the ratio a of the reception level U to its free space value U_o:

$$a = \frac{U}{U_o} \qquad (1)$$

we find for the two-path propagation [1]:

$$a^2 = 1 - 2\,R\cos\varphi + R^2 \qquad (2)$$

Here, R is the reflection factor: /262

$$R \leq 1$$

and ϕ is the difference of phase between direct and reflected wave. The average of a^2 is:

$$\overline{a^2} = 1 + R^2 \qquad (3)$$

For the frequencies f_1 and f_2, the expressions a_1^2 and a_2^2 differ according to Equation (2) in ϕ by

$$\Delta\varphi = 2\pi(f_1 - f_2)\tau \qquad (4)$$

The statistical relationship between a_1^2 and a_2^2 is obtained according to Equation (2) and (3) from the autocorrelation function:

$$\rho = \frac{1}{2\pi} \int_{-\pi}^{+\pi} (a^2(\varphi) - \overline{a^2}) (a^2(\varphi + \Delta\varphi) - \overline{a^2}) \, d\varphi$$

$$= \frac{2R^2}{\pi} \int_{-\pi}^{+\pi} \cos\varphi \cdot \cos(\varphi + \Delta\varphi) \, d\varphi = 2R^2 \cos\Delta\varphi \qquad (5)$$

This gives the standardized autocorrelation function:

$$\rho' = \cos\Delta\varphi \qquad (6)$$

From the recording of the two quantities a_1^2 and a_2^2 (example in Figure 1), the correlation coefficient r_t is calculated from the times with fading for time intervals t. Taking:

$$\rho' = r_t \qquad (7)$$

we obtain from (4) and (6):

$$\tau_t = \frac{\arccos r_t}{2\pi(f_1 - f_2)} \cdot \qquad (8)$$

an average time delay over the period t.

Other methods apply for the determination of the time delay statistics of the base level fluctuations or the intermodulation noise [2 - 9]. As compared with these methods, the above-described one has the advantage that the technical arrangements are very simple. We do without the demodulator and other equipment causing errors in the case of deep fading.

3. Measurement layout

The measurements were carried out over the distance between Hornisgrinde (Schwarzwald) and Feldberg (Taunus). The distance of 181 km is far above the usual radio link distances. The radio beam travels so high above the Rhine level (Fig re 2) that time delays up to 7 ns are possible with the geometrical layout.

4. Results

From the registrations of the reception level for f_1 and f_2 from March to July 1975, a pair of values was taken in times with fading per minute and the correlation coefficient for time intervals of 1 hour and 5 hours was calculated. From these we obtained according to Equation (8) the time delays τ_{1h} for 1 hour and τ_{5h} for 5-hour intervals.

From Table 1 and 2, the ranges may be seen containing the calculated values as well as the range of reliability for 95% probability. In the case of the averages from spring to summer, a decrease in time delay is found.

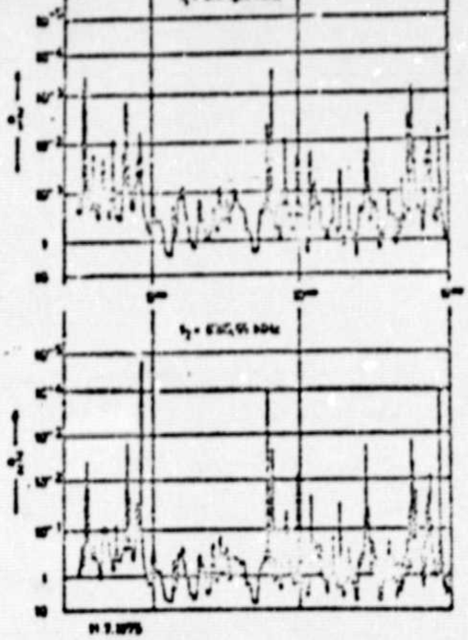

Figure 1. Example of registration

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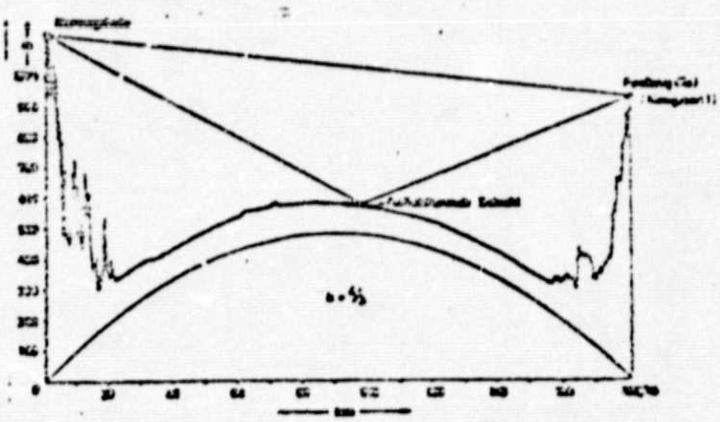

Figure 2. Ground section of the test radio link distance. The carrier frequencies of both radio link units were:

$$f_1 = 6404{,}80 \text{ MHz},$$
$$f_2 = 6315{,}35 \text{ MHz}.$$

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TABLE 1. TIME DELAY τ_{1h}/ns

	No. of evaluated hours	Measurement results lowest value	Reliability range	Maximum value	Reliability range	Average
March	10	0,82	(0,64-1,05)	1,71	(1,36-2,12)	1,20
April	20	0,51	(0,40-0,66)	2,54	(2,10-3,03)	1,22
May	30	0,60	(0,47-0,77)	1,88	(1,51-2,31)	1,15
June	30	0,37	(0,28-0,40)	1,87	(1,50-2,30)	1,11
July	30	0,42	(0,33-0,56)	2,58	(1,83-2,71)	1,03

TABLE 2. TIME DELAY τ_{5h}/ns

	Minimum value	Reliability range	Maximum value	Reliability range	Average
March	1,07	(0,97 - 1,20)	1,14	(1,03 - 1,27)	1,11
April	1,07	(0,97 - 1,20)	1,12	(1,01 - 1,25)	1,09
May	0,76	(0,68 - 0,84)	1,24	(1,12 - 1,[illegible])	1,03
June	0,79	(0,71 - 0,89)	1,05	(0,94 - 1,16)	0,90
July	0,73	(0,66 - 0,82)	1,75	(1,59 - 1,92)	1,09

The histogram of Figure 3 shows the frequency distribution of τ_{1h} for the total studied interval. In the 5-hour sections, τ_{1h} fluctuates on the average by 0.8 ns. These fluctuations are also the cause of the difference between the sum frequency curves for τ_{1h} and τ_{5h} (Figure 4). The distributions deviate considerably from the normal ones. /264

It is planned to compare the time delays determined according to the method described here with the values obtained from pilot level fluctuations and intermodulation noise, to test how far the modulation disturbances in radio link can be described by the two-path propagation.

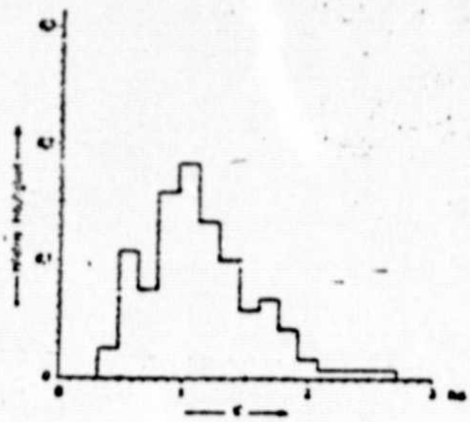

Figure 3. Frequency of τ_{1h} in the total studied interval

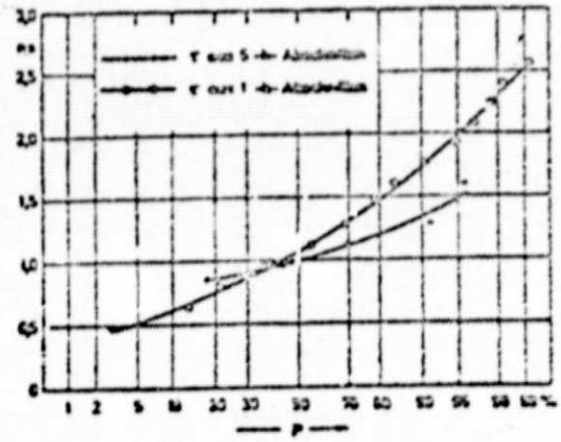

Figure 4. Distribution of τ_{1h} and τ_{5h}

Translator's note. Text in the figure is illegible.

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