Investigation on EHF Radio Link Availability in Bulgaria

Boncho G. Bonev[1], Metodi P. Yankov[2], Kliment N. Angelov[3]

Abstract – **The attenuation of the EHF radio waves in hydrometeors, especially in rain, and in the earth's atmosphere severely affects the quality of a radio link, working in that frequency range, and limits its path length. In the present article a study on the quality of a radio link, working on the 30-100GHz range, is made, using the ITU models for rain and atmospheric attenuation, and the Crane global model for rain attenuation. The results show, that in the 67-100GHz range the attenuation does not increase significantly, and therefore that range can be successfully used for independent radio link, as well as a part of a FSO/RF communication systems. The research is made based on actual statistical rain rate data for the Bulgarian region.**

Keywords – **EHF, rain attenuation, atmospheric gaseous attenuation, link availability.**

I. INTRODUCTION

The constant demand of higher data rates requires the use of higher frequencies, such as the EHF (30-300GHz) range, for radio transmission. Radio links, working in that range can be used independently, as well as a part of a hybrid FSO/RF communication system. The EHF diapason is very practical for use in those systems, because of its atmospheric propagation characteristics. They can successfully compensate the disadvantages of the optical wave propagation, used in the FSO systems.

The imminent problems that occur when using millimeter waves are the high losses, caused by absorption and scattering by the atmospheric gases, as well as by the hydrometeors, especially rain [1 – 4]. The atmosphere is completely transparent for frequencies below 3 GHz. Above that frequency the radio waves are significantly absorbed by hydrometeors, and above 20 GHz – by the atmospheric gases [5, 6, 9].

In our previous researches, the link availability was investigated for a number of typical geographic regions in Bulgaria – Sofia, Smolyan etc., using the ITU model [11 – 13] for rain attenuation. In the present article that study is done for Bulgaria overall, using the Crane global model. The difference in this model is that it takes into account the rainfall length in depending on rain rate, when the total losses in the rain are calculated.

II. THEORETICAL ANALYZIS

Lets analyze a radio link with a length d[m], working on frequency f [GHz], respectively wavelength λ [m]. The received power, P_r [dBm] can be derived from the following equation:

$$P_r = P_t + G_t - L + G_r\,, \qquad (1)$$

where P_r is received power in dBm, P_t – transmitted power in dBm, G_t,G_r are gains of the transmitter/receiver antenna in dBi, L - total propagation losses in dB.

The total losses are due to three major factors – free space loss, attenuation in the atmosphere, and attenuation in rain:

$$L = L_{FS} + L_{atm} + L_{rain}\,. \qquad (2)$$

The free space losses are calculated by the well known expression [6]

$$L_{FS} = 20\lg\frac{4\pi d}{\lambda} = 20\lg\frac{4\pi df}{c}\,, \qquad (3)$$

where c=3.10^8 m/s is the light speed in vacuum.

The losses in the atmosphere are given by the formula:

$$L_{atm} = L_{sp\_atm}.d/1000\,, \qquad (4)$$

where L_{sp_atm} is the specific attenuation in the atmosphere, dB/km [9].

The rain attenuation L_{rain} in dB as defined by the Crane global model [5, 7] is:

$$L_{rain} = k.RR^{\alpha}\left(\exp(y.\delta)-1\right)/y\,, \text{ when } 0 < d < \delta \qquad (5)$$

and

$$L_{rain} = k.RR^{\alpha}r\,, \qquad (6)$$

where

$$r = \frac{\exp(y.\delta)-1}{y} + \frac{\left(\exp(z.d)-\exp(z.\delta)\right).\exp(0.83-0.17\ln RR)}{z}\,, \qquad (7)$$

when $\delta < d < 22.5\,km$.

In Eq. (5) and (7) δ in km is

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$$\delta = 3.8 - 0.6 \ln RR \, . \qquad (8)$$

And *y* and *z* are defined as follow

$$y = \alpha \left[\frac{0.83 - 0.17 \ln RR}{\delta} + 0.26 - 0.03 \ln RR \right] \qquad (9)$$

$$z = \alpha . \left(0.026 - 0.03 \ln RR \right) . \qquad (10)$$

In equations (5-9) *RR* is the rain rate, *k* and α are frequency and polarization depending coefficients and can be taken from [8].

We can see from equations (2) – (10), that the total propagation losses of the radio link are frequency, distance, and rain rate dependant $- L(f, d, I)$.

From expressions (1) – (10), using numerical methods, we can calculate the maximum rain rate, at which we still have connectivity - $RR_{\max}$.

If for the given radio link the transmitted power P_t, antenna gains G_t and G_r, receiver sensitivity for a given *BER* - P_{r_min} and the frequency *f*, are constants, $RR_{\max}$ will depend only on the link distance *d* - $RR_{\max}=RR_{\max}(d)$. Then, when we have the statistical rain rates data for the geographical region, and more important, the percentage of time, when the rain rate exceeds a certain point - *p(RR)=p(RR'>RR)* based on the function $RR_{\max}(d)$, we can calculate the exact percentage of time, when the connectivity will be lost - *p(d)* [10]

$$p(RR) = p\left(RR(d)\right) = p(d) \qquad (11)$$

III. NUMERICAL RESULTS

The above equations are used for a theoretical calculation of the link breakage probability for radio links working in the 30-100 GHz frequency range. In order to do that, the rain rates statistical data for Bulgaria is used. The percentage of time, when the rain rate exceeds a certain point $p(RR)$ is shown on Fig. 1.

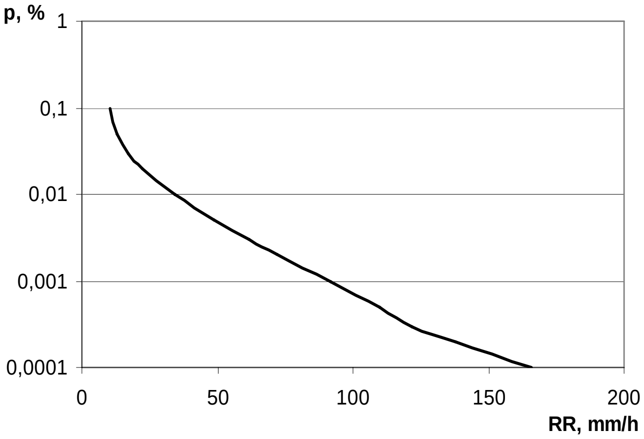

Fig.1. Rain rate statistic for Bulgaria

The function from Fig. 1 has been interpolated with the following expression

$$p,\% = 10^{A.RR^6 + B.RR^5 + C.RR^4 + D.RR^3 + E.RR^2 + F.RR + H} , \qquad (12)$$

where the values of the constants *A, B, C, D, E, F* and *H* are given in Table 1. The error of this approximation is calculated to be 0.15%.

TABLE I. VALUES OF APPROXIMATION CONSTANTS

A	B	C	D	E	F	H
4.87E-12	***-2.79E-9***	***6.36E-7***	***-7.3E-5***	***4.426E-3***	***-0.1507***	***0.1082***

The link constants are as follows P_t = 10 dBm, antennas diameter is fixed and for *f*=60 GHz their gain is $G_t = G_r$ = 43 dBi and receiver's sensibility is $P_{r\_\min} = -60$ dBm.

The coefficients *k* and *α* can be determined from [8] and the specific attenuation in the atmosphere from [9].

In Fig. 2 - Fig. 5 are presented the values of maximum rain rate and the values of link breaking probability depending on frequency *f* and radio link distance *d*.

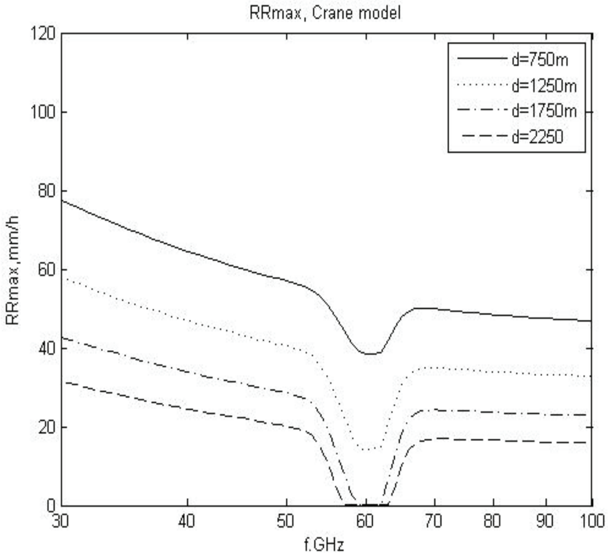

Fig. 2. Maximum rain rate depending on frequency for different values of link distance.

Fig. 2 shows that in frequencies of 67 – 100 GHz the maximum admissible rain rate $RR_{\max}$ is varying a little and it is slightly lower than in frequencies 40 – 55 GHz.

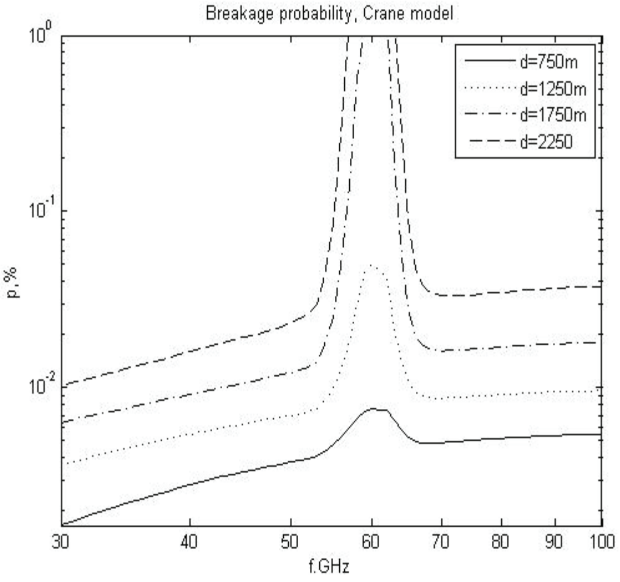

Fig. 3. Link breaking probability in %, depending on frequency for different link distance.

Fig.3 show that the minimum breaking probability is achieved at frequencies from 30 to 55 GHz but for these frequencies the data rate will be smaller than in frequencies of 67 – 100 GHz where the breaking probability is greater, but remain of the same order. Therefore we can say that the frequency range 67 – 100 GHz is better for this type of links because it provide greater data transmission speed on approximately same distances as the range 30 – 55 GHz.

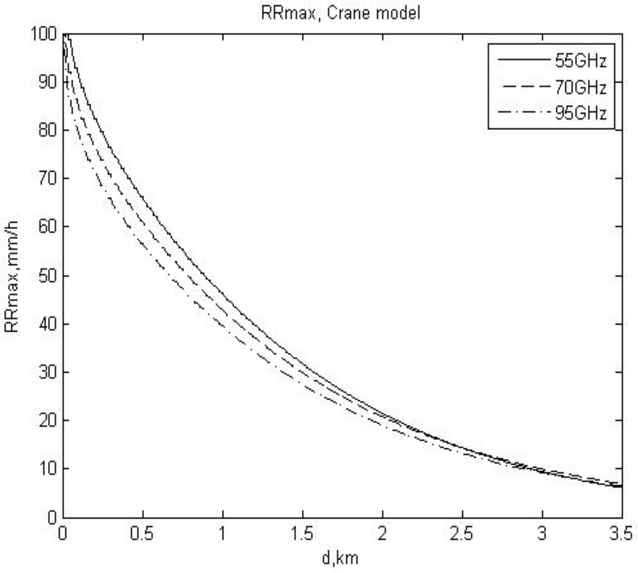

Fig. 4. Maximum rain rate depending on link distance for different values of frequency.

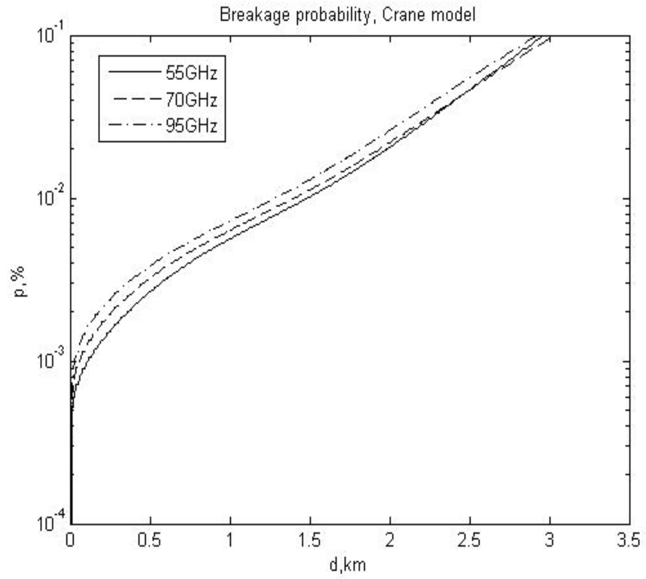

Fig. 5. Link breaking probability in %, depending on link distance for different frequencies.

Fig. 4 and Fig. 5 show that if a link breaking smaller than 0.01% is required, the link distance is limited to 1,2 – 1,4 km for the studied frequencies.

IV. CONCLUSION

The frequencies in the 67 GHz – 100 GHz diapason can be used for radio links on distances of about 1 km with link availability greater than 99.99%, which is sufficient enough for some type of radio links. The rain attenuation at higher frequencies is greater, but in this case a narrower beam, and respectively the higher antenna gain can be produced with the same sized antenna as for the lower frequencies. Furthermore, in this case, the link distance is almost the same as in lower frequencies if the same sized antennas are used.

If the greater than 1 – 1.5 km distances or greater than 99.99% link availability have to be achieved, the hybrid Free-Space Optics/Radio Frequency (FSO/RF) communication links can be used.

In our previous works [11 – 13], a similar study for different Bulgarian regions was done, using the ITU model. These studies show that the Crane model calculates significantly higher losses than calculated by the ITU model for the same rain rates. Therefore, the connections break probability is about one order higher, when calculating by the Crane global model. This significant difference in the results demands a practice realization and experimental researches on EHF radio link in studied frequency diapason for a more accurate analysis of the studied problem.

ACKNOWLEDGEMENT

Scientific researches whose results are presented in this paper are financed by Internal competition of Technical University of Sofia.

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