ANALYSIS OF THE MODEL FOR CALCULATING THE RADIO LINKS MILLIMETER RANGE ENERGY BUDGET

Kremenetskaya Y. A, Ph. D., Zhukova E. R., Morozova S.V.
State University of telecommunications, Kyiv, Ukraine

The main limiting factor in the model for calculating the radio coverage energy budget, including in the millimetre range (MMD), usually considered the attenuation in free space, which is present in the formula of Friis (1):

$$\frac{P_1}{P_2} = G_1 G_2 \left(\frac{\lambda}{4\pi d} \right)^2, \quad (1)$$

where P_1 is the received power, P_2 is the transmitted power, G_1 and G_2 the gain of the transmit and receive antennas, respectively, λ is the transmission wavelength, d – is the transmission range.

In the formula (1) used a known parameter, as the damping in the "free" space $L_{\text{FSL}} = \left(\frac{\lambda}{4\pi d} \right)^2$, from which analysis we can conclude that with increasing frequency requires increasing the signal power. Formula (1) was first published in 1945 for radio meter and decimeter wavelengths, which are absorbed at that time.

However, for millimeter range systems, which uses a narrow directional diagram of the less than one degree antennas, maybe needs a different approach for evaluating the energy budget, where the main losses are the attenuation in the atmosphere (Fig.1), the scattering of the signal in urban areas (the trees), the loss due to the beam divergence, the hardware limitations of modulators (photodetectors) for the phase noise, Doppler effect, etc.

For example, professionals such as Zhou P., Farooq H. (Samsung Electronics) [1], Shakhnovich I. [2] say the error of this model for MMR systems with a narrow radiation pattern. And even Sklyar B. [3] focuses on the geometric damping effect in the "free" space in the transmission path for a particular frequency between two isotropic antennas.

It is therefore necessary to perform a mathematical model for calculating energy losses in a radio link of MMR, to fully assess the potential of radio systems operating in this range. If you take that energy directional transmitter power is distributed within the solid angle Ω (for small angles of aperture α < 1 deg Ω $\approx \frac{\pi\alpha^2}{4}$) uniformly and to take into account the path loss is only due to the beam divergence and attenuation in the atmosphere L_{atm}:

$$P_1 = P_2 \frac{\pi\alpha^2 d^2}{4 A_2 L_{\text{atm}}}, \quad (2)$$

A_2 - effective area, which can be taken for the area dS of the host antenna. In classic textbooks on the radio (for example, in [4]) the effective area A_2 is determined by the ratio

$$A_2 = \frac{D_2 \lambda^2}{4\pi}, \qquad (3).$$

- where D_2 the gain of the receiving antenna (for transmit antenna $D_1 = \frac{4\pi}{\Omega}$).

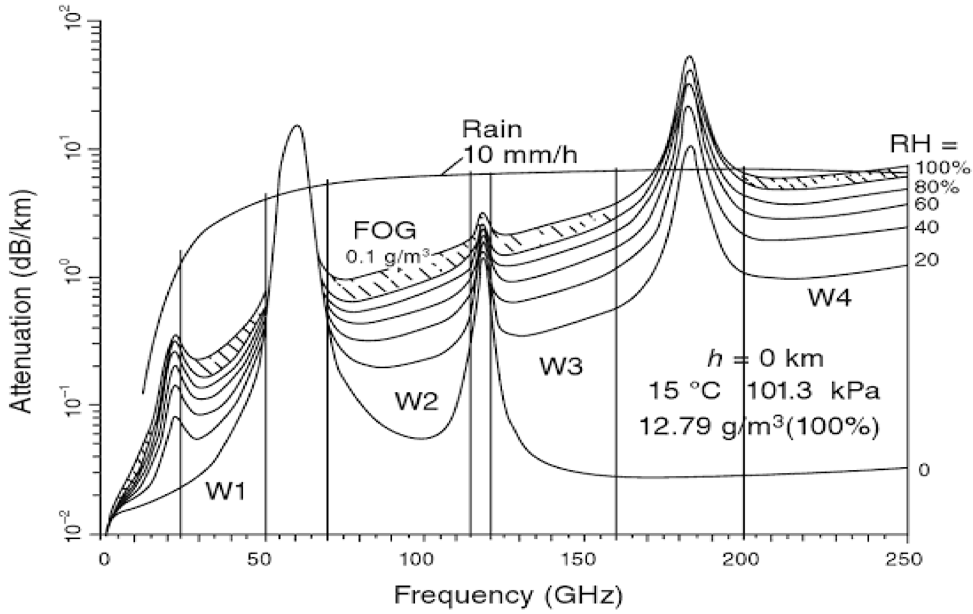

Fig.1. Specific atmospheric attenuation at sea level for different levels of humidity (RH), including fog and rain, W1-W4 – transparency window of the atmosphere.

However, if we use relation (3) in (2), we get that with decreasing wavelength the energy potential of the radio will increase, which is contrary to the formula of Friis (1) where an inverse relationship.

If we take the opening angle of the radiating antenna 1 deg, the area of the receiving antenna 1 cm^2, the order of sensitivity of the receiver 10^{-10} W, which corresponds, for example, for equipment ALFOplus80, where the receiver sensitivity -68/-74 dBm. For different attenuation coefficients in E-band(W2) (see Fig.1) get an approximate dependence is shown in Fig.2.

The main limiting factor in the model for calculating the radio coverage the MMR energy budget is probably not the attenuation in free space, which is present in the formula of Friis (1).

To assess the energy efficiency of MMR systems requires a different calculation model that takes into account limiting factors, such as the physical features of millimeter range radio signals distribution, formation and radiation, as well as a modern compensatory methods, such as MIMO technology, adaptive methods diagrammatology in complex urban and weather conditions, various hybrid techniques based on the photoelectric conversion signal of MMR.

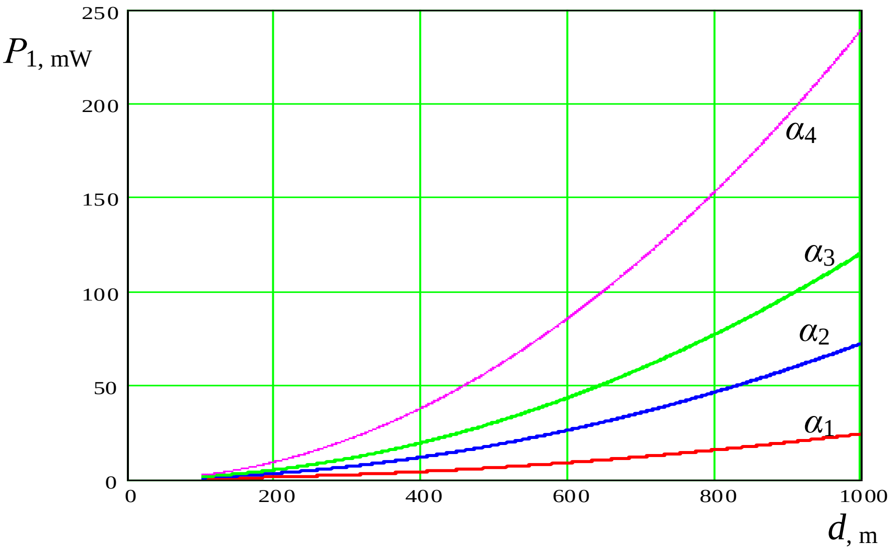

Fig.2. The transmitter power dependence of the distance calculated by the formula (2) with different attenuation coefficients: α_1=10 dB/km, α_2=15 dB/km, α_3=20 dB/km, α3=25 dB/km for the E-band with a 10 dB reserve budget

References

1. Жоую Пи. Введение в широкополосные системы связи миллиметрового диапазона / Жоую Пи, Фарук Хан // Электроника: наука, технология, бизнес. – 2012. – № 3. – С. 86-94

2. Шахнович И. Миф о затухании свободного пространства: чего не писал Г. Т. Фриис / И. Шахнович // Первая миля. - 2014. - № 2. - С. 40-45.

3. *Скляр*, Б. *Цифровая связь. Теоретические основы ипрактическое применение* / Б. *Скляр. — Изд. 2-е, испр. Пер.* с *англ. — М.:Издательский дом "Вильямс". — 2003. —* 1104 с.

4. Долуханов М. П. Распространение радиоволн / М.П. Долуханов. — М.: Связь, 1972. — 336 с.

Abstract

In the article it is shown that for systems of millimeter band basic path loss are not associated with the attenuation in free space and with the physical features of radio signals distribution, formation and radiation.

Keywords: millimeter range, the Friis model, the attenuation in free space, the energy budget of the radio link.

Анотація

В роботі показано, що для радіосистем міліметрового діапазону основні втрати в тракті пов'язані не з загасанням сигналу в вільному просторі, а з фізичними особливостями поширення, формування і випромінювання радіосигналів.

Ключові слова: міліметровий діапазон, модель Фрііса, загасання у вільному просторі, енергетичний бюджет радіолінії.

Аннотация

В работе показано, что для радиосистем миллиметрового диапазона основные потери в тракте связаны не с затуханием сигнала в свободном пространстве, а с физическими особенностями распространения, формирования и излучения радиосигналов.

Ключевые слова: миллиметровый диапазон, модель Фрииса, затухание в свободном пространстве, энергетический бюджет радиолинии.