Directional and Omnidirectional Antenna for Ricean and Rayleigh Channels

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ABSTRACT: *The Tx and Rx antennas are used for Television broadcasting and the differences between them are documented in this work. We have studied the directional and omnidirectional antenna for Ricean and Rayleigh channels. With the help of graphical presentations we have compared them with the ETSI requirements and further we did experimental observations.*

Keywords: DVB-T, BER, C/N, Ricean and Rayleigh Channels

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1. Introduction

This paper covers an investigation of the influence of the change in polarization of the electromagnetic waves by reception of DVB-T signals with a directional (log-periodic LP-21) and an omnidirectional (monopole) antenna in urban and rural conditions, by which are received direct as well as reflected signals. According to the standard [1] these are the cases of Ricean and Rayleigh channels, whose mathematical descriptions are presented with the distributions of Rice and Rayleigh.

Figre 1 (right side) shows the case of reception of DVB-T signals in urban conditions, where there are lot of buildings with different emplacement and height. The antennas can be mounted on different sides of the building, different floors or on the roof, whereat part of them will receive directed signal (Gaussian channel) or directed and reflected signals with directed and undirected antenna (Ricean and Rayleigh channel). In Fig. 1 (left side) is presented the case of reception of DVB-T signals with the use of directional and omnidirectional antennas in rural environment, where the buildings are small and spread [2, 3, 4].

In both cases the reception of signals is implementable with the already aforementioned antennas with vertical and/or horizontal polarization. There are different reasons use reception of broadcasted with vertical polarization signals with antennas installed for horizontal polarization and vice versa.

Furthermore, it is known that in the case of reflections, under certain conditions, the polarizations of the broadcasted signal changes in the place of reception [5]. Also, when the antenna is installed, it is possible that the antenna is not oriented for horizontal or vertical polarization, but has a displacement in left or right in relation to the vector of the electric field. This displacement can range from few degrees to several tens of degrees in the vertical or horizontal plane, whereat signals broadcasted with vertical polarization are received with antenna oriented for reception of signals that have neither horizontal nor vertical polarization. By the suggested methodology for investigation are also considered the reception with one antenna for vertical polarization of local programs and transboundary reception of signals with horizontal polarization (without rotating the antenna), as well as the influence of other radiocommunication systems: LTE, WiMax, DTT, etc. [6, 7, 8].

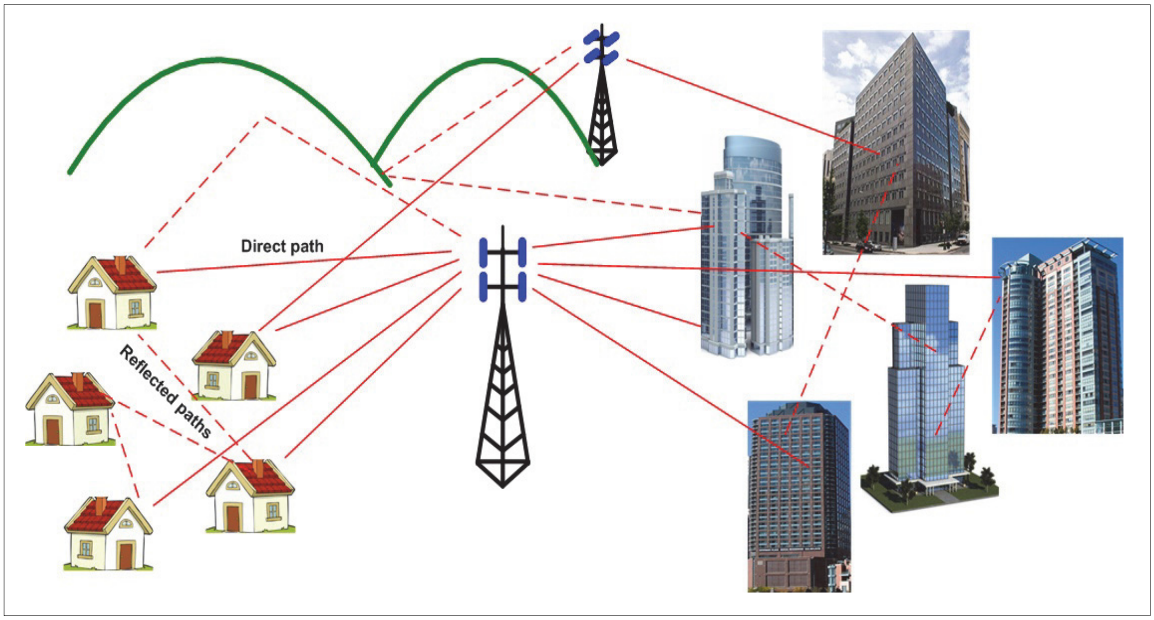


Figure 1. Multipath reception in DVB-T

2. Mathematical Relationships

The reception of DVB-T signals is accompanied with a variety of specifics and difficulties, as essential are the influence of the carrier-to-noise ratio, which is different for the different modulation of the carrier signals, different degrees of the convolution code, as it is also dependent on the type of the connection channel. According to [1], by television reception there are three types of connection channels distinguished:

a) Gaussian channel - characterized with the reception of the broadcasted directed signal from the transmitter, through directed reception antenna. In this case, the mathematical description of the connection channel is presented by Gaussian distribution, respectively AWGN noise.

b) Ricean channel – characterized with a reception, with the use of directed reception antenna, when there are reflected signals. The mathematical description (modeling) of this connection channel is presented by Rice distribution:

$$y(t) = [\rho_o x(t) + \sum_{i=1}^{N} \rho_i e^{-j\theta_i} x(t-\tau_i)] / \sqrt{\sum_{i=0}^{N} \rho_i^2} \tag{1}$$

where: - the first term before the sum represents the line of sight ray;

- N is the number of echoes equal to 20;

- Θi is the phase shift from scattering of the i'th path;

- ρi is the attenuation of the i'th path;

- τi is the relative delay of the i'th path.

The Ricean factor K (the ratio of the power of the direct path (the line of sight ray) to the reflected paths) is given as:

$$K = \rho_o^2 / \sum_{i=1}^{N} \rho_i^2 \qquad (2)$$

A Ricean factor K = 10 dB has been used in the simulations. In this case:

$$\rho_o = [10 \sum_{i=1}^{N} \rho_i^2]^{1/2} \qquad (3)$$

c) Rayleigh channel – characterized with receiving via omnidirectional receiver antenna (dipole/monopole) at the presence of reflected signals. The mathematical description is being presented by a Rayleigh distribution:

$$y(t) = k \sum_{i=1}^{N} \rho_i e^{-j\theta_i} x(t - \tau_i) \qquad (4)$$

where

$$k = 1/[\sum_{i=1}^{N} \rho_i^2]^{1/2}$$

In Table 1 are presented the minimal allowed (limit) values of the carrier-to-noise ratio for a non-hierarchical modulation for $BER = 2.10^{-4}$ after a Viterbi decoding and Quasi Error Free (QEF) receiving after the Read Solomon decoder [1, 9].

The carrier-to-noise ratio that is needed at the place of receiving depends on the Effective Radiated Power (ERP)from the transmitter. In many cases though, the maximal ERP is limited by the possible interference with the existing radio transmitters of other signals. Hereof there is a research made on the dependence of BER and the carrier-to-noise ratio from the intensity E of the field at the place of receiving.

	Required C/N for BER = 2x10^{-4} after Viterbi QEF after Reed-Solomon			
Modulation	**Code rate**	**Gaussian channel**	**Ricean channel**	**Rayleigh channel**
16-QAM	1/2	8,8	9,6	11,2
16-QAM	2/3	11,1	11,6	14,2
16-QAM	3/4	12,5	13,0	16,7
16-QAM	5/6	13,5	14,4	19,3
16-QAM	7/8	13,9	15,0	22,8
64-QAM	1/2	14,4	14,7	16,0
64-QAM	2/3	16,5	17,1	19,3
64-QAM	3/4	18,0	18,6	21,7
64-QAM	5/6	19,3	20,0	25,3
64-QAM	7/8	20,1	21,0	27,9

Table 1. The minimal allowed (limit) values of the c/n

The intensity E of the electromagnetic field at the place of the antenna mount is defined/calculated according to the expression [10]:

$$E\ [\text{dB}\ \mu\text{V/m}] = U + 6 - \left(G + \lambda_{dB} + k\right) \quad (5)$$

where U is the level of the DVB-T signal at the place of the measurement (at the input of the level strength meter); G is the gain by voltage of the antenna (dB); $k\ [dB] = -l.\ a$, where l is the length of connecting coaxial cable and a is its attenuation for 100m at a given frequency; $\lambda\ [m] = c/f$, and c = 300 000 *km/s* is the speed of light in vacuum and f is the carrier frequency for the relevant television channel ($f \equiv f_c$).

3. Experimental Results

On 01.10.2013 in Bulgaria the aerial transmission of television channels was fully switched to DVB-T, and the polarization of the signals from the multiplexes was changed to a vertical. The late analog television transmission used a horizontal polarization and so the antennas were oriented (mounted) for this polarization. Most of the users of this service are still using their antennas with a horizontal polarization. Few years ago, this change aroused my interest to research the characteristics of this type of emitting and receiving a DVB-T signal from different multiplexes – local and remote (Table 2). The measurements were made with pointed antenna with a direct receiving and receiving of reflected signals. Later the research was broadened by conducting the measurements with omnidirectional antenna (monopole). Unfortunately, due to the deactivation (suspension of the transmission) of most multiplexes in the region of Sofia, only the channels 27, 40 and 49 were left. Since the transmitter of ch. 49 is more than 40 kilometers away from the place, where the measurements took place, the intensity E of the electromagnetic field is low. By receivinghe signal trough both antennas, there is not enough level and quality of the DVB-T signal, so this makes it's modelling via Ricean and Rayleigh channel impossible.

TV channel	**f_c, MHz**	**U, dBµV**			
		Gaussian		**Ricean**	
		H	**V**	**V**	**H**
23	490	56	53	55,7	45
32	562	30	36,6	33,5	<20
40	626	49,6	38,6	55	43,6
49	698	29,6	<26	38,4	<22
52	722	49	37,9	54,3	43,1
53	730	30,9	<23	28,6	<19
64	818	37,2	41,3	42,9	35

Table 2. The characteristics of dvb-t signals

The presented results are for the experiments, made with two antennas (directional and omnidirectional), receiving channels 27 and 40 of the UHF band. The parameters of the received channels are presented in Table 3. The measurements are made for the two most severe cases: Ricean and Rayleigh channel. Because the broadcasting of DVB-T signals is with a vertical polarization, the change of the slope of the installation for each antenna starts from 0 ° to 90 ° through a 10 ° step, where the initial position shown in Figure 2, and the polarization of the radio waves of the transmitting and receiving antennas are the same (vertical). In its end position, the antenna receives with horizontal polarization, although the transmitter does not change its polarization (vertical). In Table 4 and Table 5 are presented the result for the levels of the signals for each channel, their carrier-to-noise ratio, BER before Viterbi (CBER), after Viterbi (VBER) and MER. In Figure 3 and Figure 4 are presented the dependence of BER from the angle of incline of the antenna, respectively for LP-21 and monopole.

In Table 6 (LP-21) and Table 7 (monopole) are presented the values for carrier-to-noise (C/N) ratio from the intensity E of the electromagnetic field at the point of receiving by different angles of incline (angle of rotation). The graphic interpretation

TV channel	27	40
B, MHz	8	8
FFT mode	8 K	8 K
M-QAM	16-QAM	64-QAM
Δ (GI)	1/16	1/4
Code	2/3	2/3
Compression	MPEG-4	MPEG-4
Profile	HP@L3.O	MP@L3.0

Table 3. The parameters of the received channels

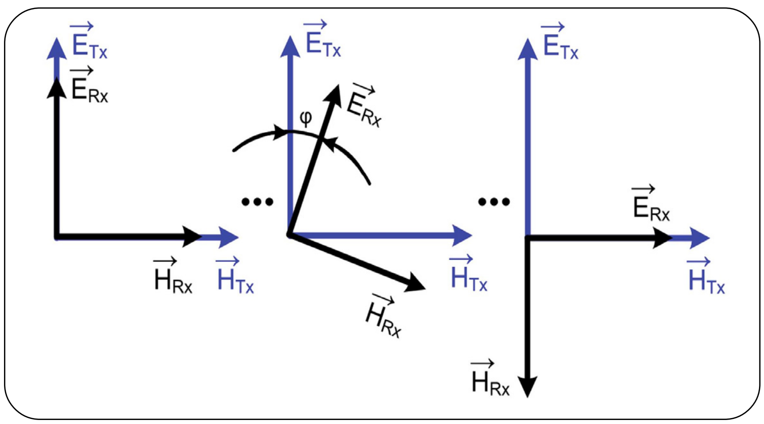


Figure 2. Change in polarizations between Tx and Rx antennas

TV channel	27		40	
fc, MHz	522		626	
Polarization	V	H	V	H
U, dBμV	41,4	37,5	46,5	45,1
C/N, dB	15,2	11,4	19,6	18
CBER	8,1E-03	2,2E-02	2,2E-02	3,2E-02
VBER	2,3E-08	2,5E-06	3,7E-08	1,2E-07
MER, dB	17,3	15,4	21,1	19,2

Table 4. The results for LP - 21

is shown on Figure 5. In the obtained values for the intensity E of the electromagnetic field are considered the parameters of the connecting coaxial cables, the gain of the antennas, the levels of the signals and the wave length of every channel.

TV channel	27		40	
fc, MHz	522		626	
Polarization	V	H	V	H
U, dBμV	36,9	38,3	41,0	40,4
C/N, dB	10	11,9	14	12,6
CBER	2, 0E-02	1, 5E-02	5, 6E-02	6, 9E-02
VBER	2, 8E-07	8, 5E-08	1, 8E-05	1,2E-04
MER, dB	15,5	16,5	16,6	16,5

Table 5. The results for monopole

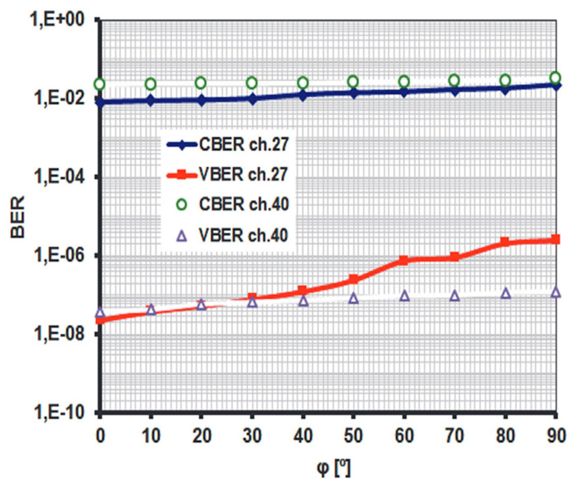


Figure 3. *BER = func(φ)* – Ricean channel (LP-21)

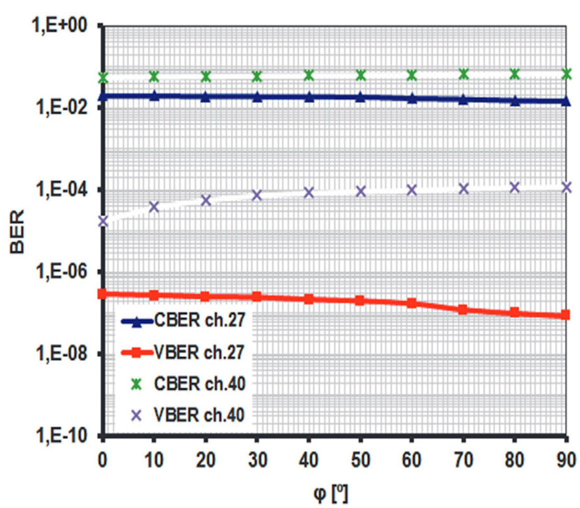


Figure 4. *BER = func(φ)* – Rayleigh channel (monopole)

TV channel	27		40	
fc, MHz	522		626	
Polarization	V	H	V	H
E, dBµV/m	50,43	46,53	57,18	55,78
C/N, dB	15,2	11,4	19,6	18

Table 6. *c/n* and *e* for lp-21

TV channel	27		40	
fc, MHz	522		626	
Polarization	V	H	V	H
E, dBµV/m	57,96	59,46	63,73	63,13
C/N, dB	10	11,9	14	12,6

Table 7. *c/n* and *e* for monopole

Constellation diagrams are presented in Figure 6.

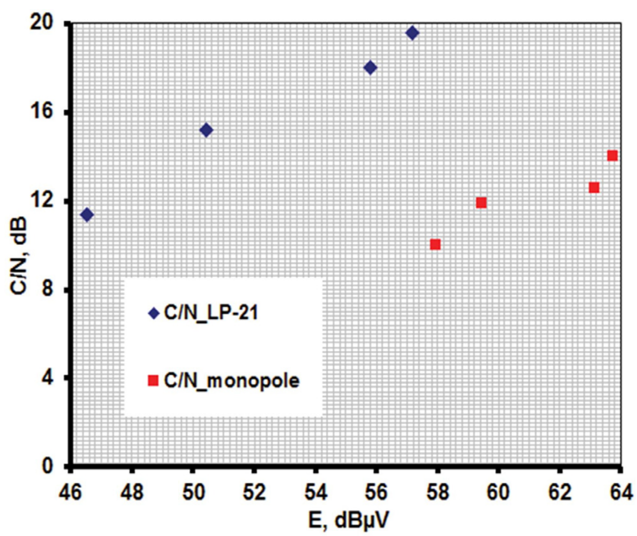


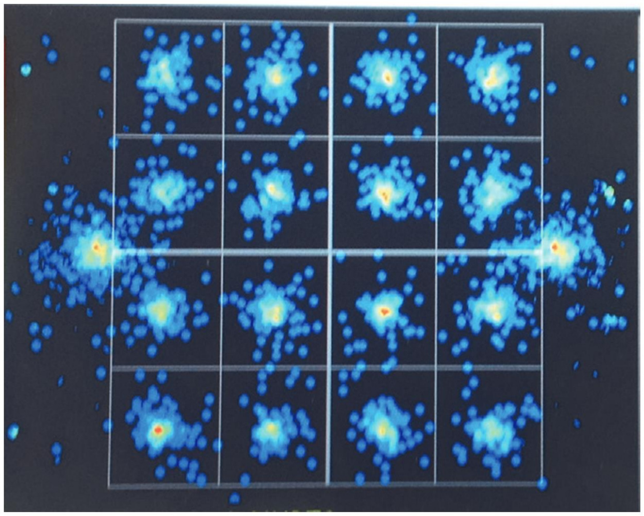
Figure 5. *C/N = func(E)*

4. Conclusion

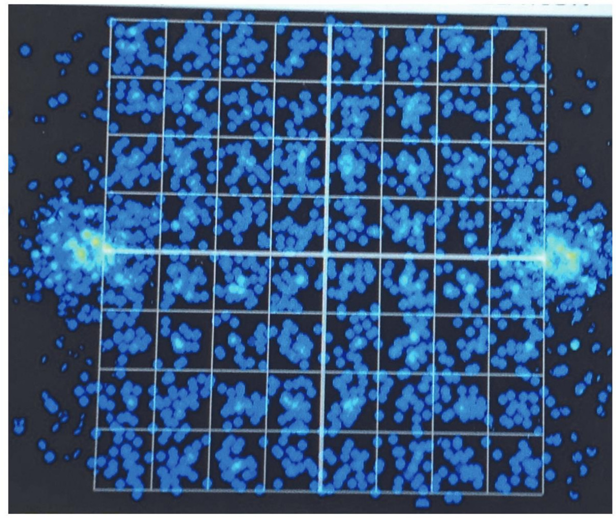
By comparison of the obtained results for the two channels, received with directional and omnidirectional antennas, it is to be seen, that the data presented in table and graphic type allow the following conclusions to be made:

• C/N ratio by directional antenna is in the permissible limits according to the standard ETSI (Table 1) for the two television channels with Gaussian and Ricean channels;

• C/N ratio by omnidirectional antenna is between 4dB and 5dB lower than the values of the standard ETSI (Table 1) for the



(a) Ricean channel



(b) Rayleigh channel

Figure 6. Constellations

two television channels with Rayleigh channel;

• For ch.27, when using a monopole antenna, the levels at horizontal polarization/position are higher than those at vertical because of the shift of the polarization from vertical to horizontal, as a result of the reflection from the buildings; the frequency is lower than this of channel 40 and the lower guard interval 1/16.

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