FDSS Downlink Capacity in Urban Zone Near Digital Video Broadcasting Installations

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Abstract. *The FDSS macrocell downlink capacity is evaluated for macrocells that operate at the same frequency of the Digital TV station (DTV) and that are nearby the DTV installations. It has been founded that the cell capacity is not affected when the distance between the DTV installations and the macrocell is more than 25 km. For lower distance, the effect is high and the downlink vanishes at a distance less than 2.1 km.*

Keywords

DTV, FDSS, cell capacity.

1. Introduction

Kaleh proposed an OFDM spread spectrum system that has carriers with disjoint frequency support and studied its performance in partial band Gaussian jamming [1]. He derived the optimal receiver and showed its performance and, in addition, showed a sub optimal receiver. The carriers in the system are orthogonal to each other and, most often are generated using the discrete Fourier transform. The previous mentioned system has the name of Frequency Diversity Spread Spectrum (FDSS).

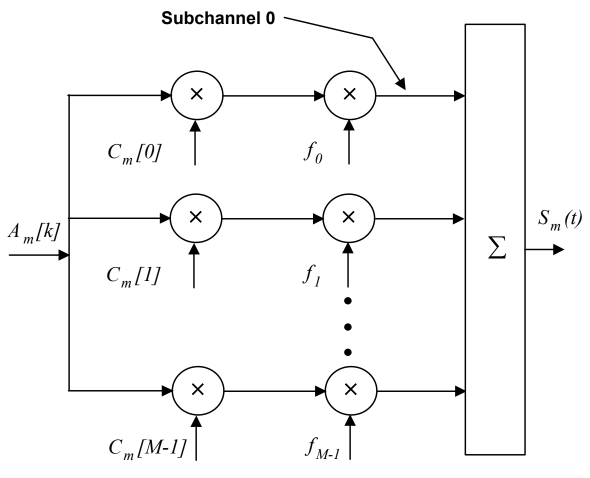

Fig. 1. The FDSS transmitter model.

COFDM is a system of modulation well-suited to the propagation and interference environment of digital terrestrial television broadcasting (DVB-T) in the UHF bands. It uses a large number of carriers, each carrying a small part of the total coded data rate. The frequency spacing is carefully chosen to ensure "orthogonality" - the carriers do not crosstalk one to the other, despite having spectra, which overlap in the frequency domain [2].

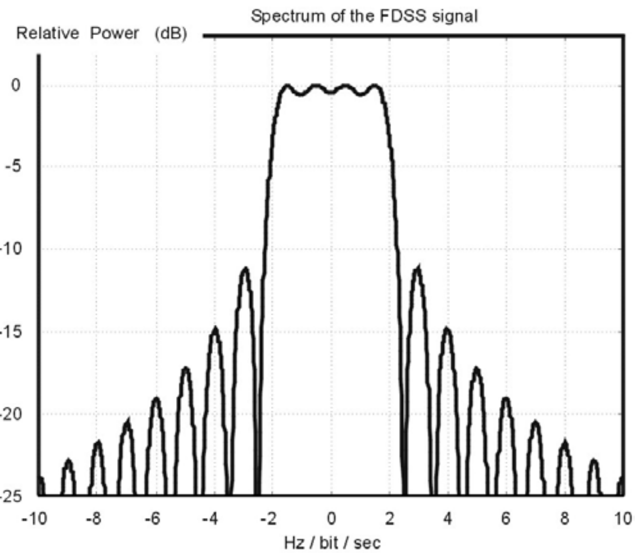

Fig. 2. The FDSS spectrum when $M = 8$.

The aim of this article is to determine the FDSS macrocells downlink capacity, which operates in the same band of the digital TV. In this case the FDSS downlink is totally jammed by the digital TV signal.

2. The FDSS model

The generation of the FDSS can be described as follows. A single data symbol with a time duration (T_b) is replicated into M parallel copies (M = 32 to 1024). For the m-th user, the i-th branch data of the parallel stream is multiplied by a chip c_m [i] from a PN code or some orthogonal code of length M and then **BPSK** modulated on to a subcarrier (f_i) spaced a part from its neighboring subcarriers by $1/T_b$. Fig. 1 depicts the transmitter model. The transmitted signal consists of the sum of the outputs of these branches. This process yields a multi-carrier signal with the subcarriers containing the coded data symbol with a processing gain of the FDSS system of M. FDSS spectrum can be viewed in terms of source bit rate; at a higher source bit rate, FDSS signal enlarges its bandwidth for a constant process gain. Fig. 2 shows a generalized FDSS spectrum in terms of source bit rate when $M = 8$. The receiver model can be shown in Fig. 3.

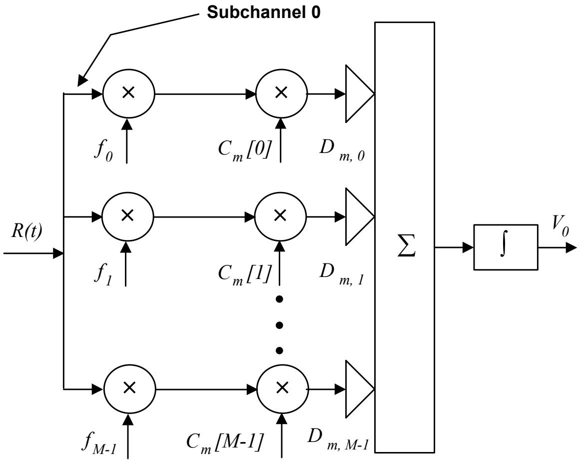

Fig. 3. The FDSS receiver model.

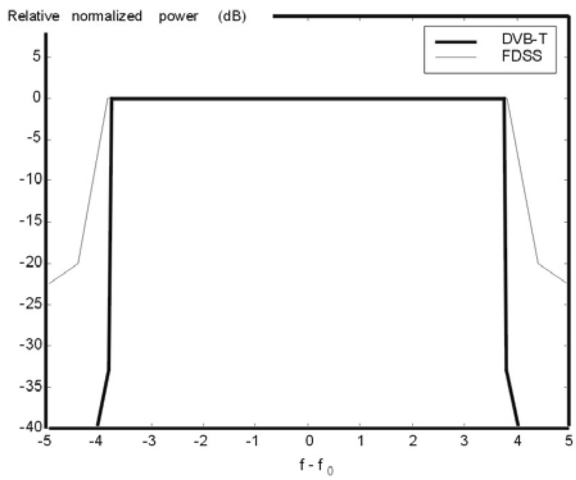

Fig. 4. The FDSS and digital TV (DVB-T) spectrum.

3. Digital Terrestrial Television Interference

The basic formula for the median propagation loss given by Hata [3] is given by:

$$L\,[dB] = 69.55 + 26.16\log(f_{MHz}) - 13.82\log(h_{TV}) - a(h_m) + [44.9 - 6.55\log(h_{TV})]\log(d_{km}) \tag{1}$$

where f_{MHz} is the frequency of the transmitted signal [MHz], $h_{TV} = 50$ m is the antenna height of digital TV transmitter, d is the distance between the digital TV transmitter and the mobile receiver [km], and $a(h_m)$ is the mobile antenna height-gain correction factor given by:

$$a(h_m) = 3.2\,[\log(11.75h_m)]^2 - 4.97\,. \tag{2}$$

The total DTV path loss L in linear unit is given by:

$$L = 10^{(L[dB]/10)}\,. \tag{3}$$

The DTV interference power is defined as:

$$P_{\text{int}}(DTV) = P_{DTV}\;G_{DTV}\;G_2\,/\,L\;, \tag{4}$$

where P_{DTV} is the DTV transmitted power, G_{DTV} is the DTV transmitter antenna gain, G_2 is the mobile receiver antenna gain assumed to be 0 dB [4].

Fig. 4 shows the FDSS and the DTV spectrum where both spectra are displayed in frequency respect the central carrier (f_0).

4. Urban Large City Macrocellular Loss

We assume that the base station antenna height (h_1) is 30 m and that the antenna gain is 15 dB. The macrocells are assumed to exist in urban (large city) zone. The propagation loss exponent n [3] is given by

$$n = 4.49 - 0.655\log(h_1)\,. \tag{5}$$

For this case, the propagation loss between the base station and the user under consideration is given by [3]:

$$L_{FDSS}\,[dB] = 69.55 + 26.16\log(f_{MHz}) - 13.82\log(h_1) - a(h_m) + [44.9 - 6.55\log(h_{TV})]\log(R_{km}) \tag{6}$$

where R_{km} is the macrocell radius in km.

The macrocell propagation loss L in linear unit is given by:

$$L_{FDSS} = 10^{(L_{FDSS}[dB]/10)}\,. \tag{7}$$

The macrocell propagation loss L_{FDSS} is the loss between two isotropic antennas.

5. The Macrocell Capacity

We assume that the user under consideration is at the intersection of three macrocells (worst case condition). To calculate the ratio E_b/N_0, we assume the following consternates:

$P_{st}(max) = 20$ W [4] ,

where $P_{st}(max)$ is the base station maximum transmitted power;

$P_{users}(max) = 17$ W [4] ,

where $P_{users}(max)$ is the maximum power transmitted to the all users. The difference between $P_{st}(max)$ and $P_{users}(max)$ is due to the pilot signal and the common channels.

$P_{su}(max) = 0.5$ W for voice users [3] ,

$P_{su}(max) = 2.0$ W for data users [3] ,

where $P_{su}(max)$ is the base station maximum transmitted power for one user.

The transmitted power for the user under consideration is given by:

$$P_u = \min\left[P_{su}(max),\ P_{users}(max)/N_u\ \alpha\ F\right] \quad (8)$$

where N_u is the cell capacity, α is the source activity factor and F is the power control reduction factor ≈ 0.5 [5].

Since L_{FDSS} is calculated between two isotropic antennas, then the received desired signal level P_r between directive antennas is given by:

$$P_r = G_{bs}\ G_2\ P_u / L_{FDSS}\ , \quad (9)$$

where G_{bs} is the base station antenna gain.

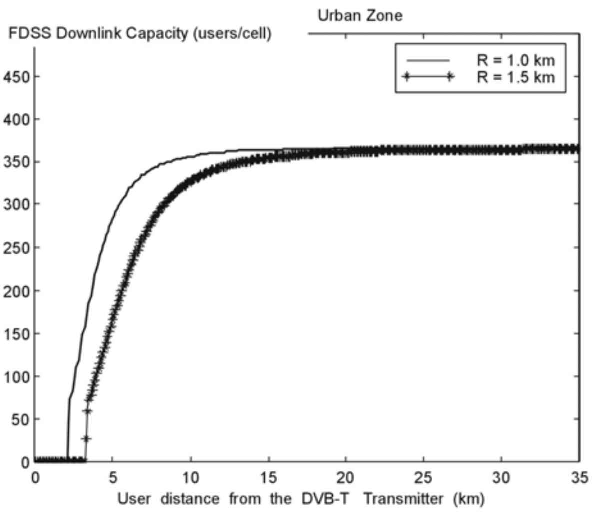

Fig. 5. The urban zone macrocell performance (voice only users).

The total multi-user FDSS interference signal is calculated using:

$$\begin{aligned} P_{int}(FDSS) \approx\ & G_{bs}\ G_2\ sect\ \frac{[(1-\phi)+Q]}{L}\ \cdot \\ & \cdot\ \min\left(P_{st},\ N_u\ P_{su}\ \alpha\ F\right) \\ & +\ G_{bs}\ G_2\ sect\ \frac{[(1-\phi)+Q]}{L}\ \cdot \\ & \cdot\left[P_{st}(max)\ -\ P_{users}(max)\right] \end{aligned} \quad (10)$$

where $sect$ = 1/3 is the sectorization factor for ideal three sectors, ϕ is the orthogonality factor of the downlink users, Q is the other cells interference [5] defined as

$$Q \approx 2 + 3\left[\frac{R}{2R}\right]^n + 6\left[\frac{R}{2.62\,R}\right]^n\ , \quad (11)$$

where R is the cell radius.

Now the total interference power is given by

$$P_{int}(total) = P_{int}(DTV) + P_{int}(FDSS) + Noise\ , \quad (12)$$

where $Noise$ is the mobile receiver noise power.

The ratio C/I is given by:

$$(C/I)_{FDSS} = P_r / P_{int}(total)\ , \quad (13)$$

and the ratio E_b/N_0 is defined as:

$$E_b / N_0 = G_p\ (C/I)_{FDSS}\ , \quad (14)$$

where G_p is the FDSS process gain, which equals to M.

From eqns. 8, 10, 13 and 14, we can notice that the ratio E_b/N_0 is a function of the number of users. The macrocell capacity is calculated by increasing the number of users from one user and calculating E_b/N_0 till it reaches the value $(E_b/N_0)_{req}$. The macrocell capacity will be the maximum number of users for which $E_b/N_0 \geq (E_b/N_0)_{req}$.

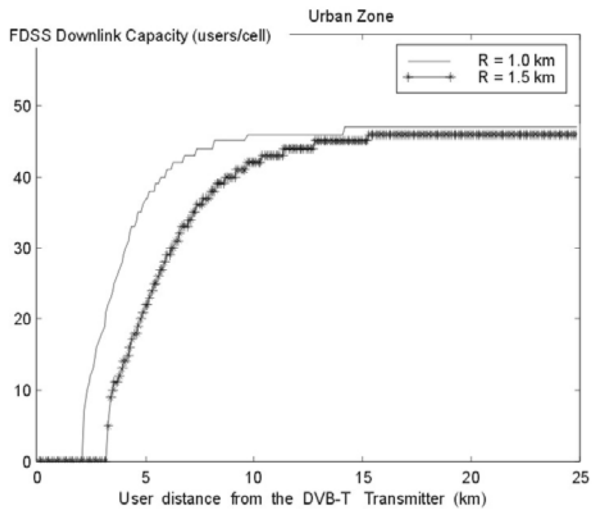

Fig. 6. The urban zone macrocell performance (data only users 144 kbit/sec).

6. Numerical Results

We assume the following general case:

- $sect = 0.4$ (for non ideal three sectors),
- $\phi = 0.5$ [4],
- $N_{rec} = -100$ dBm (assuming a noise figure of 7 dB),
- $P_{DTV} \cdot G_{DTV} = 10$ kW,
- $f_{MHz} = 800$.

First we study the case of voice only users. We assume the following [3]:

- $G_p = 512$,
- $\alpha = 0.5$,
- $(E_b/N_0)_{req} = 7$ dB.

Fig. 5 shows the macrocell capacity as a function of the distance between the user under consideration and the DTV transmitter for two different cell radii (1 and 1.5 km). For a cell radius of 1 km, we can notice that the capacity is null when the distance is less than 2.1 km and it increases with the distance. When the distance is 25 km or more we get the maximum possible capacity.

Secondly, we study the case of data only users (UDD 144 kbit/sec). We assume the following [3]:

- $G_p = 53$,
- $\alpha = 1.0$,
- $(E_b/N_0)_{req} = 3$ dB.

Fig. 6 shows the macrocell capacity as a function of the distance between the user under consideration and the DTV transmitter for two different cell radii (1 and 1.5 km). For a cell radius of 2.1 km, we can notice that the capacity is null when the distance is less than 1 km and it increases with the distance. When the distance is 15.5 km or more we get the maximum possible capacity.

7. Conclusion

The macrocell downlink capacity has been calculated for urban zones near to DTV installations. It has been found that the downlink capacity vanishes very near to the DTV transmitter. At a distance of 2.1 kilometres, for the data users case and for the voice users case the capacity begins to increase from zero when the cell radius is 1 km. At a distance of 25 km or more, the DTV effect is null.

References

[1] KALEH, G. Frequency Diversity Spread Spectrum Communications to Counter Bandlimited Gaussian Interference. *IEEE Transactions on Communications*. 1996, vol. 44, no. 7, p. 886 - 893.

[2] ETS 300 744. *Digital Video Broadcasting*. March 1997.

[3] CALVO-RAMÓN, M. Third Generation IMT-2000 (UMTS) Mobile Communication Systems. *Fundación Airtel Vodafone*, 2002. In Spanish.

[4] HOLMA, H., TOSKLA, A. *WCDMA for UMTS*. New York: John Wiley and Sons, 2000.

[5] LEE, J. S., MILLER, L. E. *CDMA Systems Engineering Handbook*. London: Artech House, 1998.

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