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Digital Television Broadcasting from HAPs

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Abstract: - The downlink of digital television broadcasting from High Altitude Platforms (HAPs) is analyzed. The minimum required transmitted power is investigated for different scenarios (LOS, NLOS and Indoor Reception). For a city like Madrid, 5 Watts of transmitted power is sufficient to get full coverage with outdoor reception, while, for larger cities (with a radius of 25km), 20 Watts is the required transmitted power. For 10 W of transmitted power and 8 dB shadowed outdoor antenna, the range is 8.6km.

Key-Words: - Digital TV, HAPs

1 Introduction

Use of the platform for radio communication and broadcasting is being considered as a possible application. Broadcasting from a stratospheric platform at an altitude of 22km is equivalent to broadcasting from the top of a 22 km-tall tower. In comparison with a terrestrial broadcasting system using a conventional tower, the angle of elevation from a receiving point to the transmitting point is large, and the probability of a direct line of sight between the two points is very high.

Because of the high altitude of the transmission platform, free space propagation is highly probable, and for that few Watts of transmitted power is needed to get a reasonable coverage.

In [1], a preliminary flight test program an broadcasting using high altitude platform stations has been given giving the values of the test parameters for different types of aerial vehicle.

In [2], the results of the test of digital television broadcasting from stratosphere has been given for the case of outdoor reception without any shaded reception. It has been concluded that a transmission power of 1 Watt is sufficient for 20 km coverage when the receiving antenna points toward the high altitude platform.

The aim of this work is to study the downlink of digital television broadcasting from high altitude platform for different scenarios. LOS, NLOS and indoor reception will be investigated in this work.

2 Downlink Analysis

We assume that a X-inverted dipole antenna is used in both of HAP station and the reception point. With a vertical 3 dB beam width of 92°, while the vertical 15 dB beam width is 180°. The X-inverted dipole antenna gain is 8 dB. The free space propagation loss L_{fs} measured in dB is given by:

$$L_{fs}(dB) = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (1)$$

where

• d is the distance between the HAP station and the receiving antenna,

• λ is the wavelength.

Building penetration loss L_p measured in dB is assumed to obey the following relation:

$$L_p(dB) = 6 + 4\left(\frac{\alpha}{90}\right) \quad (2)$$

where α is the penetration angle in degree measured from horizon.

The thermal noise of the TV receiver N is given by:

$$N(dBm) = -114 + NF + 10\log_{10}(B)_{MHz} \quad (3)$$

where NF is the TV receiver noise figure in dB.

The minimum detectable signal S measured in dBm is given by:

$$S(dBm) = N + SNR_{req} \quad (4)$$

where SNR_{req} is the required Signal to Noise Ratio to have a given bit error rate.

We will study the performance of the proposed system assuming that the operating frequency is 650 MHz and that the TV signal has a 7.6 MHz bandwidth [3]. We will assume that the TV tuner has a 6 dB noise figure. Thus, for good reception, the received TV signal must have a level of -78 dBm or higher, i.e., with SNR of 21 dB or more [3]. For the top-roof antenna, the feeder loss is assumed to be 4

dB meanwhile for the indoor antenna, the feeder loss is assumed to be 1 dB.
The received signal power P_r is given by:

$$P_r = P_t + 2G - L_{fs} - L_f - L_{other} - M \quad (5)$$

where

- P_t is the transmitted power,
- G is the HAP antenna gain in the direction of the receiving antenna,
- L_f is the sum of feeder losses in both the transmitter and receiver,
- L_{other} is the loss due to other effect such as diffraction,
- M is the downlink margin assumed to be 5 dB to compensate (the antenna gain change and the path loss change) as a function of frequency in the full UHF TV band.

In the uplink which works at a frequency of 2 GHz, an antennas (for the very small earth station) with 3 dB beam-width of 25^o X 25^o and a gain of 16.5 dB could be used. In the HAP, a receiving antenna with 3 dB beam-width of 35^o X 35^o and a gain of 13 dB could be used. In the uplink a total feeder loss of 4 dB is assumed. Using a transmitter with 1 Watts of transmitted power, the uplink SNR ratio will be greater than 30 dB.

3 Results

Firstly, we study the case when the roof-top receiving antenna is in line of sight with the HAP station. Fig. 1 shows the receiving signal level as a function of the distance from the HAP sub-point for three different transmitting power (2.5, 5 and 10) Watts. It can be noticed that the coverage radius is 12.4, 17.5 and 22.6km respectively.
Next we study the case when the roof-top receiving antenna is shadowed by a higher nearby building. We will assume that the shadowing loss is 8 dB. Fig. 2 shows the receiving signal level as a function of the distance from the HAP sub-point for three different transmitting power (2.5, 5 and 10) Watts. It can be noticed that the coverage radius is 8.6km when the transmitted power is 10 W.
Then we study the case of indoor reception (with wall penetration loss) assuming an indoor antenna with 1.5 dB gain. Fig. 3 depicts the receiving signal level as a function of the distance from the HAP sub-point for three different transmitting power (2.5, 5 and 10) Watts. It can be seen that the received signal has a power level lower than -78 dBm, thus a good indoor reception will not be possible.
Next we study the effect of the vertical HAP stability on the system performance. Fig. 4 shows the receiving signal level as a function of the distance from the HAP sub-point for a transmitting power of 10 Watt and LOS case. It can be noticed that, for height change of 4km, the system coverage radius has a little bit difference compared to the height difference. The coverage range has a value of 21.8km to 23.3km.
For a large city as Madrid with a radius of about 15km (see Fig. 5), we can have TV full coverage when the transmitting power is in the order of 5 watts necessary to have a coverage of more than 15 km (outdoor reception) assuming a position keeping radius of 2.0km. For larger cities (radius of 25km), we have to have a transmitting power in the order of 20 Watts.
Fig. 6 shows the inverted X dipole gain as a function of the receiving angle.
Fig. 7 shows the block diagram of the HAP payload. Table 1 shows the required performance of each block of the payload.

4 Conclusion

The downlink of digital television broadcasting from High Altitude Platforms (HAPs) has been analyzed. The minimum required transmitted power has been investigated for different scenarios (LOS, NLOS and Indoor Reception). For an outdoor reception a transmitting power of 5 watts is sufficient to cover all Madrid Capital mean while for larger cities a transmitting power of 20 Watts will be sufficient. Also it has been noticed that with 10 Watts of transmitted power the coverage radius will be 8.6km when the outdoor receiving antenna is 8 dB shadowed by near by building.

References:

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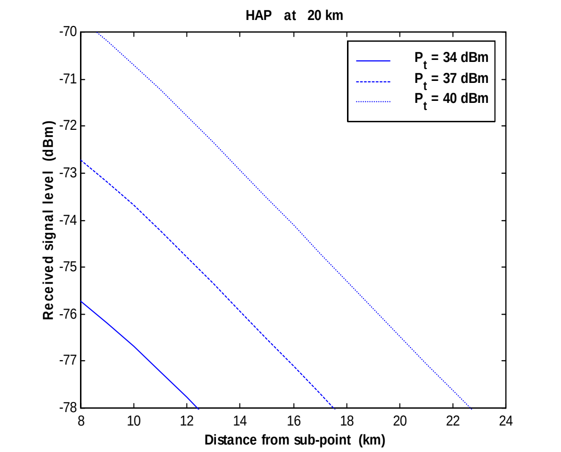

Fig. 1: The received signal level as a function of the distance from the HAP sub-point for three different transmitting power, (LOS) case.

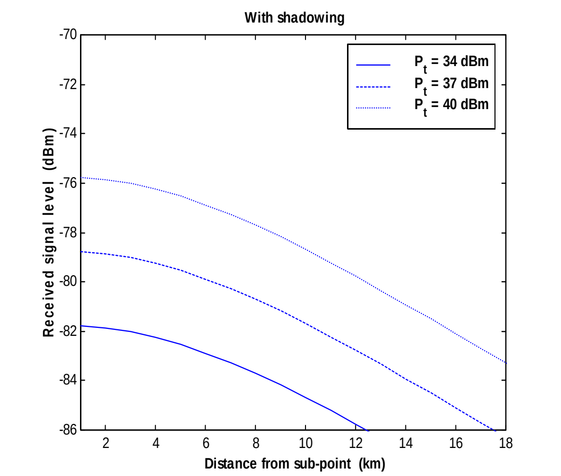

Fig. 2: The received signal level as a function of the distance from the HAP sub-point for three different transmitting power assuming 8 dB shadowing.

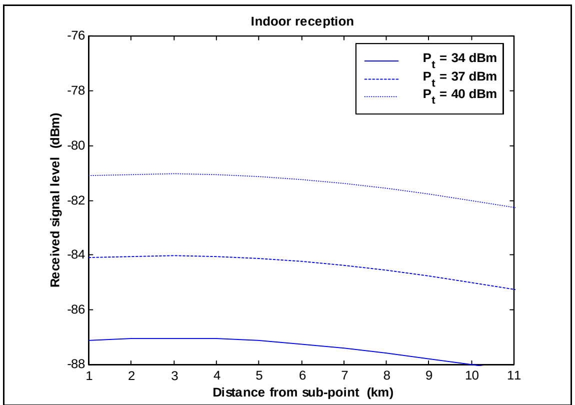

Fig. 3: The received signal level as a function of the distance from the HAP sub-point for three different transmitting power, (indoor reception) case.

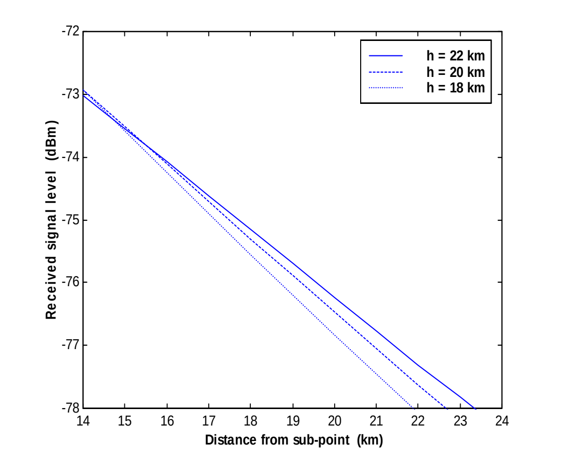

Fig. 4: Effect of the HAP height stability on the coverage of the system.

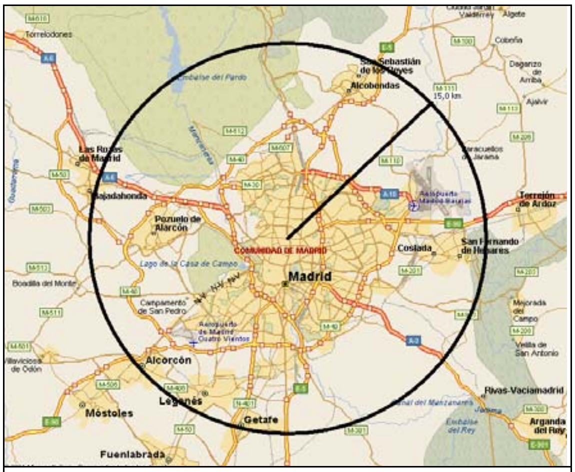

Fig. 5: Map of the city of Madrid.

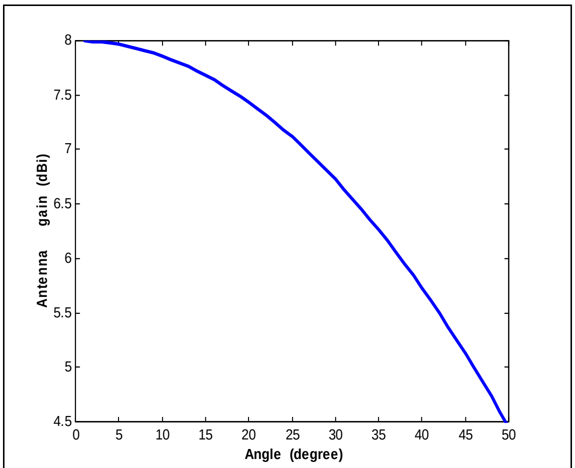

Fig. 6: The X-inverted dipole gain.

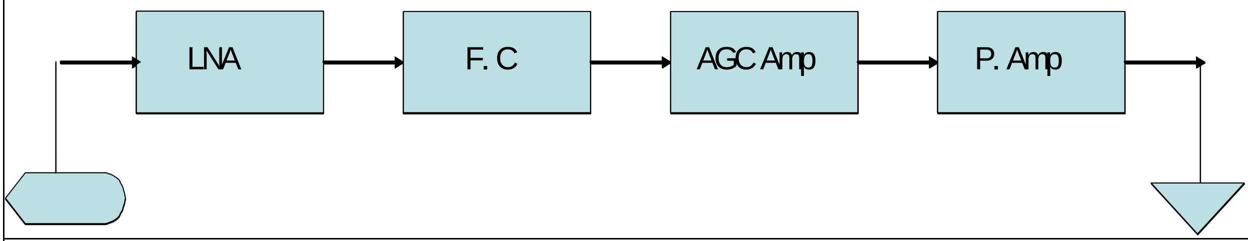

Fig. 7: Block diagram of HAP payload.

Table 1: HAP payload required performance.

Block	**Performance**
Low noise amplifier	**Gain = (30 ± 2) dB, Noise Figure = 1 to 2 dB**
Frequency Converter	**Conversion loss < 10 dB, Local oscillator power < 10 dBm**
AGC amplifier	**Gain = (54 – 66) dB**
Power amplifier	**Gain = (30 ± 1) dB, Pout = (5 to 10) W**