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Evaluation Of Required Receiver Antenna Gain And Dimension For Analog And Digital Satellite Tv Transmission Link

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***Abstract*— In this paper, evaluation of required receiver antenna gain and dimension for analog and digital satellite TV transmission link is presented. The procedure and mathematical expressions for the determination of the required receiver antenna gain and dimension are presented along with case study satellite link data and numerical computations based on the data. The results show that the analog TV-satellite receiver requires antenna with diameter of 0.69 m for the given antenna efficiency of 0.6 and frequency of 11.75 GHz. On the other hand, the digital TV-satellite receiver requires antenna with diameter of 0.36 m for the given antenna efficiency of 0.6 and frequency of 11.75 GHz. It is noted that the parameters of the analog and the digital TV-satellite links are the same except that the bandwidth for the analog TV is 27 MHz while that of the digital TV is 36 MHz. Also, the required $\left[\frac{C}{N}\right]_{Required}$ for the analog TV is 14 dB whereas the required $\left[\frac{C}{N}\right]_{Required}$ for the digital TV is 7 dB. Also, the difference between the antenna gain for the analog and the digital TV is 5.750612634 dB. Essentially, there is a reduction in the required antenna gain for the digital TV by a value of 5.750612634 dB from the required antenna gain of the analog TV. In all, the smaller sized receiver antenna size will make it cheaper for consumers of the digital TV-satellite service when compared to those consumers that are using the analog TV service.**

Keywords*— *Analog TV, Digital TV, Satellite Link, Antenna Gain, TV Transmission

1. Introduction

Satellite TV is a form of television program distribution framework in which TV signals are wirelessly delivered to homes and offices across the globe via a network of outdoor antennas, satellites and broadcast centers [1,2,3,4,5,6]. TV signals from broadcast centers are sent to the satellite which in turn relays the signals to the outdoor antennas at various homes and offices across the globe. In the earlier days, the analog signals are used but nowadays, digital signals has become the mainstream mode of delivery of satellite TV programs [7,8,9,10,11,12].

The satellite TV begins with a transmitter antenna at the earth station (for the uplink) which transmits the TV signal to the satellite [13,14,15,16,17]. Then, in the downlink, the satellite relays the TV signal to the receiving earth station antenna. The uplink and downlink frequencies are usually different and both are mostly in the Ku-band (12–18 GHz) or C-band (4–8 GHz). In recent times other frequency bands are also used [18,19,20,21,22,23,24,25,26].

The choice of the frequency affects the sizes of the antennas to be used at the uplink and the downlink. Also, the c choice of analog or digital signaling approach also affect the effective antenna sizes which in turn affect the cost of the satellite link equipment. Accordingly, in this paper, the evaluation of the required receiver antenna gain and antenna dimension for analog and digital satellite TV transmission link is presented. The detailed mathematical expressions for the computations are presented along with numerical sample using a case study Ku-band analog and digital satellite TV link.

2. Methodology

The procedure and mathematical expressions for the determination of the required receiver antenna gain and dimension for analog and digital TV satellite communication links are presented. The presentation is augmented with numerical computation based on the case study satellite link data presented in Table 1.

Table 1 The case study satellite link data for the numerical example

S/N	Parameter Name	Parameter Unit	Parameter Value for Analog TV	Parameter Value for Digital TV	S/N	Parameter Name	Parameter Unit	Parameter Value for Analog TV	Parameter Value for Digital TV
1	Transmitter Antenna Diameter, D_{Gt}	m	0.8	0.8	7	Noise Temperature at the Antenna, T_A,	K	65	65
2	Transmitter Antenna Efficiency, η_{Gt}	%	60	60	8	**Bandwidth, B**	**MHz**	**27**	**36**
3	Frequency	GHz	11.75	11.75	9	Boltzmann constant, K		$1.38\ x\ 10^{-23}$	$1.38\ x\ 10^{-23}$
4	Path length, d	km	38,000	38,000	10	**The Required $\left[\frac{C}{N}\right]_{Required}$**	**dB**	**14**	**7**
5	Receiver Noise Figure, F	dB	0.9	0.9	11	Transmitter power, P_t	W	17	17
6	Reference Temperature, T_o =	K	290	290	12	Receiver Antenna Efficiency, η_{Gr}	%	60	60

2.1 Determination of the required receiver antenna gain and dimension for Analog TV satellite link

The transmitter antenna gain (G_t) in dB is given in terms of transmitter antenna diameter, D_{Gt} in meters, wavelength, λ in meters and transmitter antenna efficiency, η_{Gt} as follows;

$$G_t = 10Log\left(\eta_{Gt}\left(\frac{\pi(D_{Gt})}{\lambda}\right)^2\right) \quad (1)$$

where

$$\lambda = \frac{3 \text{ x } 10^8}{\text{f}} \quad (2)$$

where f is frequency in Hz. Then, for f = 11.75 GHz, $\eta_{Gt} = 0.6$, $D_{Gt} = 0.8$ m and π=3.141593, λ and G_t become;

$$\lambda = \frac{3 \text{ x } 10^8}{11.75 \text{ x } 10^9} = 0.025531915 \text{ m}$$

$$G_t = 10Log\left(0.6\left(\frac{3.141593(0.8)}{0.025531915}\right)^2\right) = 10Log(5813.854966) = 37.64464194\ dB$$

Given the path length, d, the pathloss in dB by free space model is given as L_{FSP} where;

$$L_{FSP} = 10Log\left(\frac{4\pi(d)}{\lambda}\right)^2 \quad (3)$$

Given that d =38,000 km, then;

$$L_{FSP} = 10Log\left(\frac{4(3.141593)(38,000,000)}{0.025531915}\right)^2 = 3.49800\ x\ 10^{20}\ W = 205.4382 \text{ dB}$$

The receiver noise figure, F = 0.9 dB and reference temperature, $T_o = 290$ K, then the receiver noise temperature, T_e is given as;

$$T_e = \left(10^{\frac{F}{10}} - 1\right) T_o \quad (4)$$

$$T_e = \left(10^{\frac{0.9}{10}} - 1\right) 290 = (1.230268771 - 1)\ 290 = 66.77794 \text{ K}$$

The noise temperature at the antenna, $T_A = 65$ K, then, the system noise temperature, T_{sys} is;

$$T_{sys} = T_A + T_e \quad (5)$$

$$T_{sys} = 65 + 66.77794 = 131.7779 \text{ K}$$

The bandwidth, B = 27 MHz and Boltzmann constant, K = $1.38\ x\ 10^{-23}$, then the noise power, N in dB is given as;

$$N = 10Log(K(T_{sys})B) \quad (6)$$

$$N = 10Log(1.38\ x\ 10^{-23}, (131.7779)27000000) = 4.91005x\ 10^{-14} = -133.089 \text{ dB}$$

The required $\left[\frac{C}{N}\right]_{Required}$ is 14 dB, then the expected received power, P_r is given as;

$$P_r = N + \left[\frac{C}{N}\right]_{Required} \quad (7)$$

$$P_r = -133.089 + 14 = -119.089 \text{ dB}$$

Given that $P_t = 17\ W = 12.30448921$ dB, then, the required receiver antenna gain, G_r is given as;

$$G_r = P_r - P_t + L_{FSP} - G_t \quad (8)$$

$$G_r = -119.089 - 12.30448921 + 205.4382 - 37.64464194 = 36.39992607\ dB$$

If the receiver antenna efficiency, $\eta_{Gr} = 0.6$, then, the diameter, D_{Gr} of the receiver antenna is given as;

$$D_{Gr} = \left(\frac{\lambda}{\pi}\right)\sqrt{\frac{10^{\frac{G_r}{10}}}{\eta_{Gr}}} \quad (9)$$

$$D_{Gr} = \left(\frac{0.025531915}{3.141592654}\right)\sqrt{\frac{10^{\left(\frac{36.39992607}{10}\right)}}{0.6}} = 0.693193 \text{ m} \approx 0.69\ m$$

2.2 Determination of the required receiver antenna gain and dimension for Digital TV satellite link

The bandwidth, B = 36 MHz and Boltzmann constant, K = $1.38\ x\ 10^{-23}$, then the noise power, N in dB is given as;

$$N = 10Log(1.38 \times 10^{-23}, (131.7779)36000000) = 6.54673 \times 10^{-14} = -131.8397569 \text{ dB}$$

The required $\left[\frac{C}{N}\right]_{Required}$ is 7 dB, then the expected received power, P_r is given as;

$$P_r - 131.8397569 + 7 = -124.8397569 \text{ dB}$$

Given that $P_t = 17\,W = 12.30448921$ dB, then, the required receiver antenna gain, G_r is given as;

$$G_r = P_r - P_t + L_{FSP} - G_t \quad (10)$$

$$G_r = -124.8397569 - 12.30448921 + 205.4382 - 37.64464194 = 30.64931343\ dB$$

If the receiver antenna efficiency, $\eta_{Gr} = 0.6$, then, the diameter, D_{Gr} of the receiver antenna is given as;

$$D_{Gr} = \left(\frac{\lambda}{\pi}\right)\sqrt{\frac{10^{\frac{G_r}{10}}}{\eta_{Gr}}} \quad (11)$$

$$D_{Gr} = \left(\frac{0.025531915}{3.141592654}\right)\sqrt{\frac{10^{\left(\frac{30.64931343}{10}\right)}}{0.6}} = 0.357539116 \text{ m} \approx 0.36\ m$$

2.3 Discussion of Results

The results show that the analog TV-satellite receiver requires antenna with diameter of $0.69\ m$ for the given antenna efficiency of 0.6 and frequency of 11.75 GHz. On the other hand, the digital TV-satellite receiver requires antenna with diameter of $0.36\ m$ for the given antenna efficiency of 0.6 and frequency of 11.75 GHz. It is noted that the parameters of the analog and the digital TV-satellite link are the same except that the bandwidth for the analog TV is 27 MHz while that of the digital TV is 36 MHz. Also, the required $\left[\frac{C}{N}\right]_{Required}$ for the analog TV is 14 dB whereas the required $\left[\frac{C}{N}\right]_{Required}$ for the digital TV is 7 dB. It can be seen that the digital TV requires smaller antenna to satisfy the smaller required $\left[\frac{C}{N}\right]_{Required}$ of 7 dB.

Notably, compared to the analog TV, the increase in the bandwidth for the digital TV increases the noise power by 1.249387366 dB from -133.0891442 dB to -131.8397569 dB. However, the reduction in the required $\left[\frac{C}{N}\right]_{Required}$ by 7 dB from 14 dB in analog TV to 7 dB in digital TV gave a net reduction of (7 - 1.249387366 dB) to 5.750612634 dB. Hence, the difference between the antenna gain for the analog and the digital TV is 5.750612634 dB. Essentially, there is a reduction in the required antenna gain for the digital TV by a value of 5.750612634 dB from the required antenna gain of the analog TV.

3 Conclusion

Determination of the antenna gain for analog and digital TV-satellite links are evaluated. The study used sample TV satellite link data to demonstrate and compare required receiver antenna gain and size for analog and digital TV-satellite links. In all, the digital TV link was found to require smaller antenna size and smaller antenna gain when compared with that of the analog TV. However, the digital TV requires higher bandwidth than the analog TV. In all, the smaller sized receiver antenna size will make it cheaper for consumers of the digital TV-satellite service when compared to those consumers that are using the analog TV service.

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