

# Passive Reception of Digital TV Signals with an Antenna

Fujio Yamada, Cristiano Akamine, Rodrigo Eiji Motoyama, and Gustavo de Melo Valeira

**Abstract**—This article aims to present a passive repeater for transmitting digital TV signals. In this article, some projects that indicate the limitations in this type of repeater are presented and in what situations it becomes suitable for use.

**Index Terms**—Band Segmented Transmission - Orthogonal Frequency Division Multiplexing (BST-OFDM), Electric field strength, Mobile reception.

## I. INTRODUCTION

THE Brazilian Digital TV System (SBTVD) signal is immune, to a limited extent, to interference and disturbances such as Gaussian noise, multipath signal, impulsive noise, the Doppler effect, and fading, due to the numerous technological resources available [1]. However, for a good image to be received, the signal presence must be above a certain level with a good quality measure in relation to Carrier-to-Noise (C/N) [2]. Situations occur in digital television reception where although there is a high-intensity Digital TV signal nearby, the location where the signal is received is in a shadowed region. The solution is to redirect this signal to the desired location via a signal relay device. However, it is not always possible to install an active relay in this high-intensity location, due to a lack of infrastructure with electricity, a high installation cost or for equipment security reasons (theft). In this case, it is desirable to develop a low-cost solution for both the installation and maintenance, that is unlikely to be stolen or vandalized. Depending on the signal level at the location, a passive repeater can be installed, this only uses antennae installed in a back-to-back configuration without the use of an amplifier [3]. It is a low-cost solution that solves the problem, in some cases. This paper presents some situations where a passive repeater is a solution.

The two most common situations for applying a passive repeater for digital TV signals are:

a) a high-intensity signal in a certain location where it is required to be redirected to a relatively distant shadowed region. For example, the summit of a hill or the top of a building, but due to the obstruction, this signal does not reach the desired location.

b) a high signal intensity on the outside of a wall or the top of the building, but due to the attenuation caused by the wall or slab the signal does not reach the internal environment where the receiver is installed.

## II. PASSIVE REPEATER DEVELOPMENT

This chapter presents a demonstration of the development and the implementation of a passive repeater for digital television using only antennae mounted in a back to back configuration. Due to the various scenarios whose parameters vary, such as the distance between the transmitter and the repeater, the location of the receiver, the power involved, and the channel frequency, this work shows the received signal conditions across the simulations adopting certain values. For conditions with other parameter values, the viability can be estimated using interpolation values. For cities that use transmitters with lower interpolation power an estimation can be made considering the ERP power in dBm between this simulation and the actual condition and adding or subtracting this value to the results shown in the subsequent tables.

### A. Signal Repeater Located far from the Receiver

The field intensity threshold of a SBTVD receiver to decode a signal is 51dB $\mu$ V/m, 90% of the time [1]. Considering a margin of 6 dB, this value becomes 57B $\mu$ V/m, which corresponds to the voltage at the receiver input (37dB $\mu$ V) for a TV channel in the 500MHz band [4].

One solution is to use a pair of passive antennae in a back-to-back configuration, separated by a metal plate to isolate the electromagnetic field in order to avoid mutual interference and pointing the receiving antenna in the direction of the best signal strength from the transmitter and directing the relay antenna to the location where you want to install the receiver. The output of the receiver from the transmitter antenna (A) must be connected to the input of the relay antenna (B) as shown in Fig. 1. The coaxial cable for connecting the antenna (C) must have the lowest attenuation possible, for example, RG6. Fig. 2 shows the repeater installation.

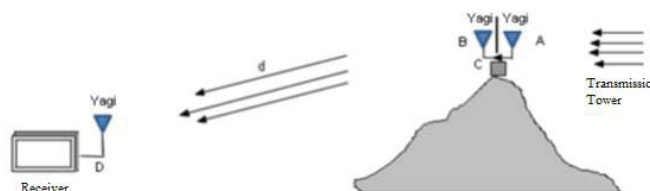


Fig. 1. Installation diagram of back-to-back passive repeater

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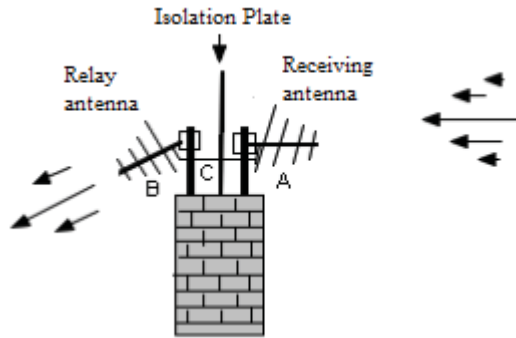


Fig. 2. Image of a back-to-back antenna installation

Table I shows the calculation of the minimum field intensity required for signal capture in the area near the receiving antenna (A) for the signal repetition to be viable, for a receiver that is located 100m, 300m or 1000m from the retransmission location and can still decode the signal.

To calculate Table I, the following assumptions were used:

- Yagi-Udo antennae were used for the repetition location, with a minimum gain of 12 dB [3] across the UHF band for both reception and retransmission. The interconnection cable between the two antennae is an RG6 with attenuation of 1 dB. Care should be taken to put the antennae in the same polarization as the antenna from the signal generating station.
- To ensure that there is no mutual interference between the antennae reception and retransmission fields, a metal plate should be placed between the two antennae of the back-to-back repeater and if possible grounded.
- A Yagi-Udo external antenna was used with the television receiver; this has a gain of 12 dB and the attenuation due to the cable connectors used is estimated at 4dB.
- It was assumed that there was no obstruction between the transmitting station antenna and either the location of the signal repeater or the TV antenna.

In practice, the system proves feasible for short distances between the reception location and the TV antenna, up to 1000m depending on the distance between the transmitting tower and the repeater location. Longer distances require active repeaters, such as a Gap Filler.

For stations located in São Paulo that installed 15kW transmitters with an approximate gain of 12 dB antenna and installed 150m high, the maximum possible distance between the transmitting tower and the repeat point is shown in Table I. For this calculation a 3dB attenuation in transmission line between 15kW transmitter, antenna, and other associated devices was considered, resulting in 81.7 dBm ERP. For this calculation, a Yagi-Udo external antenna was used with a gain of 12 dB and the attenuation of the cable and connectors was estimated at 4dB. It was assumed that there was no obstruction in visibility between the transmitting tower and repeat location. For signal conversion of dBm to BμV/m the following [4] equation can be used:

$$P(\text{dBm}) = E(\text{dB}\mu\text{V}/\text{m}) - 113(\text{dB}) + 10 \log \left( \frac{\lambda}{\pi} \right)^2 \quad (1)$$

The free space attenuation is calculated by:  $A_{el} = \left( \frac{4\pi d}{\lambda} \right)^2$  where  $\lambda$  is the wavelength and  $d$  is the distance in meters.

### B. Distance between the transmitter and repeater location

Often the maximum distance that the passive repeater can be installed from the transmitter is wanted to be known. This information can be obtained by calculating the distance in which the signal attenuates from the transmitter until reaching the repeater location (A). In most cases, this type of signal repetition is valid when using an external antenna with the receiver.

TABLE I  
 MAXIMUM DISTANCE BETWEEN THE TRANSMITTER AND THE REPETITION LOCATION FOR AN EXTERNAL ANTENNA

Distance from B to the receiver	100			300			1000		
	400	600	800	400	600	800	400	600	800
Channel frequency (MHz)	400	600	800	400	600	800	400	600	800
Transmission distance for 15kW (km)	39.4	26.9	20.2	13.6	8.9	6.6	4.1	2.6	2.0
Transmission distance for 5kW (km)	26.7	18.8	13.3	7.7	5.1	3.8	2.3	1.5	1.1
Transmission distance for 1kW (km)	10.2	6.8	5.1	3.4	2.3	1.7	1.0	0.7	0.5

The results in Table I show that the possibility of success with passive repetition depends substantially on the distance between the repetition location and the receiver antenna and the frequency of the measured channel. Table I shows that this kind of repetition is feasible for a transmitter within 5 km.

### C. Distance between the transmitter and repeater location for internal antenna at the receiver

This situation is more difficult to solve because the walls and other obstacles cause additional attenuation. Research by the Laboratorio de Televisão Digital at Universidade Presbiteriana Mackenzie showed that this attenuation varies from 4 to 7 dB depending on the construction of the wall [5]. Furthermore, it is generally an internal omnidirectional antenna with a gain of zero to three dB against the 12 dB gain of a Yagi-Udo antenna. The difference in signal level between internal and external reception is in the order of 16 dB. This means that the signal intensity at the repeater location should also be higher by the same proportion. Calculating the maximum distance for this condition, we have Table II.

TABLE II  
 MAXIMUM DISTANCE BETWEEN THE TRANSMITTER AND THE REPETITION  
 LOCATION FOR AN INTERNAL ANTENNA

Distance from B to the receiver	100			300			1000		
Channel frequency (MHz)	400	600	800	400	600	800	400	600	800
Maximum transmission distance (km)	6.0	4.0	3.0	2.2	1.5	1.6	-	-	-

Table II shows that passive repetition to a receiver with an antenna is only feasible if the shadow region is located near the tower, approximately 3 to 6 km and that the receiver is connected to a 100 or 200m repeater if a 15kW transmitter is used.

D. Signal repeater located near the receiver

Often within a building like a mall or a residence the signal level is insufficient for television signal reception. However, it is noted that externally the signal intensity is elevated. If the installation of a cable from the external antenna to the receiver device or a large antenna is not desired due to aesthetic reasons, the installation of a passive signal repeater on the external wall would be sufficient. The main function of the passive repeater in this case is to redirect the distribution of the field in the indoor environment improving coverage in certain areas while the total energy within the environment does not change [3]. This topic shows in which conditions this option is feasible. Fig. 3 outlines the signal being repeated in a closed environment.

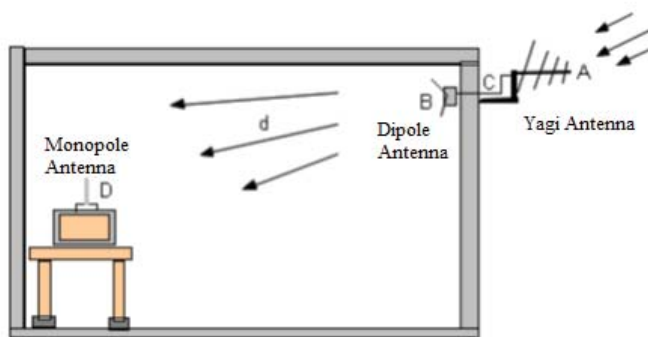


Fig. 3. Repeater near the receiver

For this version, the following assumptions were adopted:

- A Yagi-Udo antenna was used at point A with a presumed gain of 12 dB
- A dipole antenna was used as the relay antenna with a presumed gain of 5 dB
- The antenna type used was monopole omnidirectional with a 3 dB gain at the receiver.
- The reception threshold used was 57dB $\mu$ V/m with a 6dB margin
- It was assumed that there was no obstruction between the relay antenna and the receiver antenna

TABLE III  
 MAXIMUM DISTANCE BETWEEN THE TRANSMITTER AND THE REPETITION  
 LOCATION FOR AN INTERNAL ANTENNA

Distance B-D (m)	10			20			40		
Freq. (MHz)	400	600	800	400	600	800	400	600	800
Free space att. B-D (dB)	44.7	48.0	50.5	50.5	54.0	56.5	56.5	60.0	62
Antenna gain A-B (dB)	17	17	17	17	17	17	17	17	17
Receiver gain monopole antenna (dB)	3	3	3	3	3	3	3	3	3
Cable repeater losses C (dB)	1	1	1	1	1	1	1	1	1
Total att. A-D (dB)	25.7	29.0	31.5	31.5	35.0	37.5	37.5	41.0	43
Field strength in A (dB $\mu$ V/m)	82.7	86.0	88.5	88.5	92.0	94.5	94.5	98.0	100

III. EXPERIMENTS COMPLETED

To confirm the validity of the above simulations, experiments were performed, a carrier at -31dB was generated using a Rohde Schwarz generator, model SMU200A and was transmitted with an Anritsu standard dipole antenna with a 3dBi gain. The measurements were performed in a Faraday cage to avoid any signal interference present in the environment. The signal was received at the reception site for an omnidirectional monopole antenna with a 3dBi gain and was measured with an Anritsu MS8901A spectrum analyzer. Fig. 4 shows how the test structure as it had been assembled in the laboratory and the results are presented in table IV.

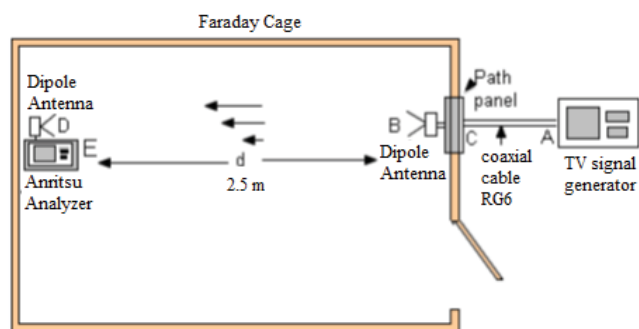


Fig. 4. Indoor signal repeater diagram

TABLE IV  
 MEASUREMENTS IN THE FARADAY CAGE

Description	Values				
Frequency (MHz)	470	500	600	700	800
Generator Level in A (dBm)	-31.4	-31.4	-31.4	-31.4	-31.4
Free space attenuation (dB)	-33.8	-34.4	-35.9	-37.3	-38.4
Antenna gain (dB)	6.0	6.0	6.0	6.0	6.0
Cable attenuation (dB)	0.4	0.4	0.4	0.5	0.5
Expected value (dBm)	-58.9	-60.2	-61.0	-62.3	-63.5
Measured value in E (dBm)	-58.7	-62.4	-62.9	-63.8	-63.7
Measured value in dB $\mu$ V/m	68.2	65.0	66.3	66.5	67.9

The measured values match the expected values, within a measurement tolerance.

#### IV. CONCLUSION

This work gives an idea of how digital TV passive repetition can be implemented and the conditions in which it is feasible. This is the presence of a minimum signal level that is stable in the signal repeater location. Normally to achieve the signal level required for passive repetition it is necessary to have visibility between the transmission and reception locations. The example calculations presented allow an interpolation to be made to determine the values for other propagation conditions. Possibly being an excellent TV signal repeating system without large implementation costs, low maintenance, and little vulnerability to theft.

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