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# DESIGN OF A VHF AND UHF TELEVISION SIGNAL BOOSTER FOR RURAL COMMUNITIES

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**ABSTRACT**

This paper is on the design of a Television Antenna Booster for Very High Frequency (VHF) and Ultra High Frequency (UHF) television channels. A clear television signal is the desire of every viewer thus, the need to have one cannot be denied. Most rural communities in developing countries are still without televisions services; with weak television signals comes a need for a low cost but efficient device that will guarantee a clear TV signal. This booster is accomplished by cascading two amplifier stages. The amplifier employed transistors as active components. With the use of shunt peaking inductors the booster is able to have a stable operation over a wide frequency range. The circuit was designed and calculated theoretical gain of the television antenna booster is 35dB.

## 1. Introduction

Television (TV), is a system involving the transmission of images and sounds to distant screens, by electronic means over electrical or fibre-optic transmission lines or by electromagnetic radiation (radio waves). TV is a vastly important medium, for a number of reasons: the amount of time that many people spend watching it (31 hours per week, for average United States adults, 25 for Britons); its ability to bring together diverse groups of people in a sense of shared national identity; and its powerful role as a source of information about experiences other than the viewer's own.

A clear television signal is the desire of every viewer. Thus, the need to have one cannot be denied. Most rural communities in developing countries are still without televisions services with weak television signals comes a need for a signal booster that will guarantee a clear TV signal.

The television Antenna Booster is an electronic device that can be used in amplifying weak TV signals from the antenna, thereby bridging the communication divide, it thus couples the antenna to the TV set.

## 2. Signal Strength

A transmitting antenna radiates a magnetic field and an electric field. The signal strength of a radiated signal is expressed in terms of the strength of the electric field. It is a measure of how many volts the electromagnetic field will induce in an antenna that is one meter long. If a receiving

**Keywords :** Television, Antenna, Booster, Signal, Amplifier.

antenna were extremely close to a transmitting antenna, the induced voltage would be expressed in volts per meter. However, normally the receiving antenna is a great distance from the transmitter, and the signal strength is only millions per meter, or even microvolts (millionths of a volt) per meter.

The field strength is dependent on the amount of power transmitted, the transmitting antenna gain, the distance from transmitter to receiver, and the path of the signal from the transmitting antenna to the receiving antenna. In designing the booster we assume very weak signals of a few microvolts.

### 3. Wideband Response Of The Booster

The television antenna booster is designed for the VHF and UHF signal ranges. This is a relatively wide bandwidth, for which output stray capacitance will have a severe attenuation effect by reducing the effective load impedance.

To obtain a flat frequency response at high frequency over a wide range low value inductors are introduced to the output circuit, this technique is known as shunt peaking.

The appropriate value of L usually lies in the range of microhenry and milihenry, final choice of inductors value is usually made by experiment, as explained by Martin (1970).

### 4. Stability – R.F Design Consideration

A major factor in the overall design is the potential stability of the transistor. A transistor is stable if there is no output signal when there is no input signal. There are two main stability factors that concern us in amplifier design;

(i) The stability factor of the transistor in use and

(ii) The stability factor of the amplifier circuit.

These stability factors are taken into consideration in the course of the Booster design.

The TV Antenna Booster was designed following the block diagram in figure 1.

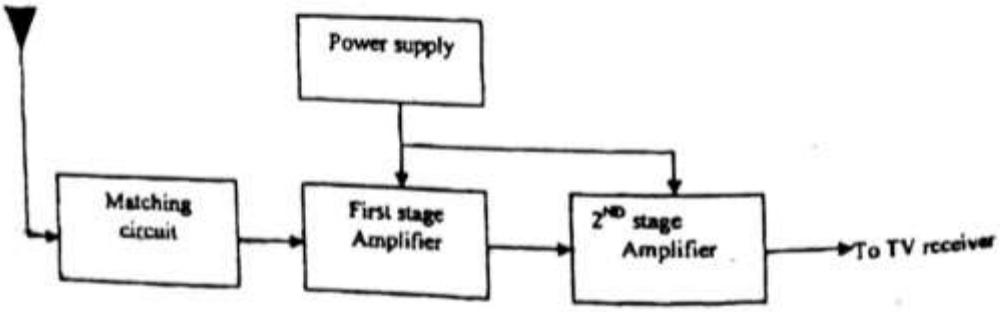


Figure 1 : The Block Diagram Of The TV Antenna Booster

The design of the TV antenna Booster was carried under some specification which include;

Input voltage - 220V a.c

| | | |
|---|---|---|
| Frequency Range | - | VHF and UHF (4MHz – 1Ghz) |
| Operating temperature | - | –5°c - 30°c |
| Storage | - | indoor |

**Impedance Matching Circuit**

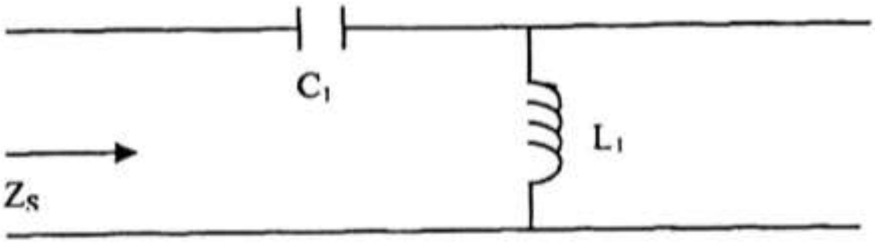


**Figure 2 :** Impedance Matching Circuit

The source impedance form the antenna is given as $Zs = 75\Omega$

Thus, as explained by Silva (2001)

$X_{L1} = 75\Omega = 2\pi fL$

$$L = \frac{75}{2\times\pi\times f}$$

The frequency is chosen along the VHF and UHF range, for this design 100 MHz is used;

$$L = \frac{75}{2\times\pi\times 100\times 10^6} = 0.01\mu H$$

$C_1$ must be chosen to cancel out this inductive reactance of 75 Ω so $C_1$ is a capacitor whose reactance $Xc = 75\Omega$

$$Xc = \frac{1}{2\pi f} \tag{1.3}$$

$$C_1 = \frac{1}{2\times\pi\times 100\times 10^6\times 75} = 0.2\,pF \tag{1.4}$$

For practical purposes $C_1$ = 102nF was used.

**Amplifier Circuit**

First Stage amplifier circuit

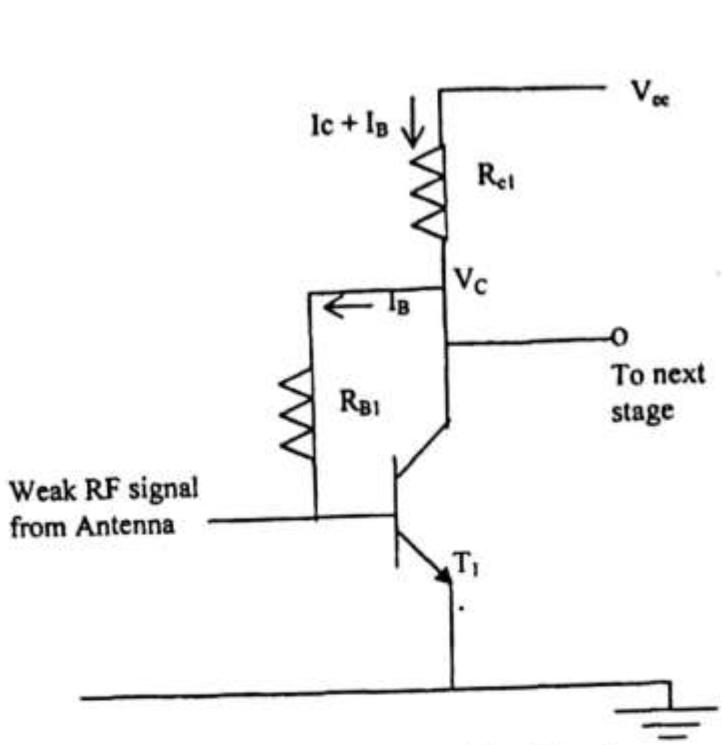


**Figure 3 :** First Stage Amplifier Circuit

From the amplifier circuit

$$I_B = \frac{(V_c - V_{BE})}{R_B}$$

and

$$V_{cc} = I_c R_c + V_c + I_B R_c$$
$$I_c = h_{fe} I_B$$

For this design the active component; transistor chosen has the following data;

C2570: NPN – Silicon, low noise UHF/NHF amplifier

$V_{cemax}$ = 30V, $h_{fe}$ = 40 min, $I_c$ = 70mA and $V_{cc}$ = 12v (chosen) $V_c = 0.5\ V_{cc}$

$\text{Freq}_{\cdot max}$ = 5Ghz.

Using equation (3.24)

$$I_B = \frac{Ic}{h_{fe}} = \frac{70 \times 10^{-3}}{40} = 0.00175A \tag{1.8}$$

$$R_{B1} = \frac{Vc - V_{BE}}{I_B} = \frac{6 - 0.7}{54} = 3.03k\Omega \tag{1.9}$$

$$R_{C1} = (Vcc - Vc)/(Ic + I_B)$$
$$= \frac{(12-6)}{(0.07 + 0.00175)} = 83.62\Omega \tag{1.10}$$

**Second Stage Amplifier Circuit**

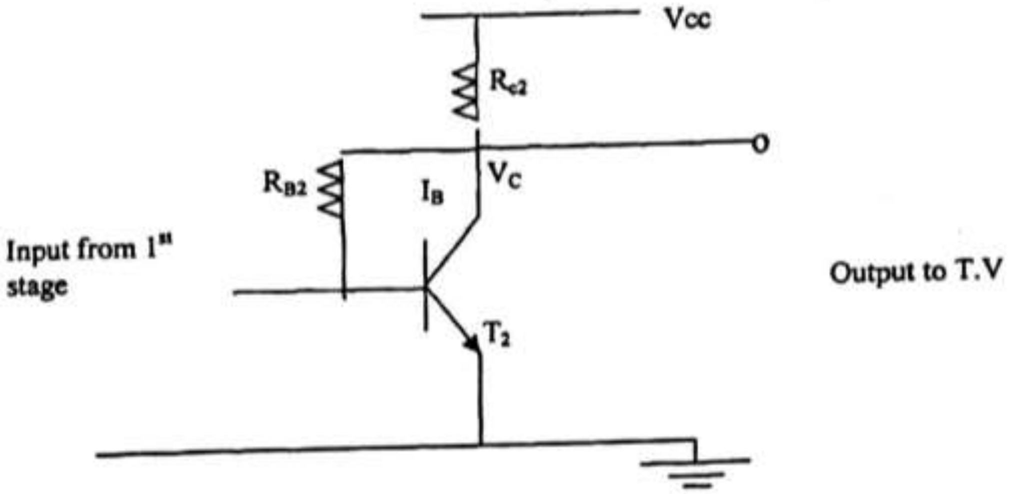


**Figure 4 :** Second Stage Amplifier Circuit

In this stage the input of the first is coupled via a capacitor $C_3$ to the second stage. Voltage feedback biasing is also used here as the emitter is connected directly to ground.

Applying the loop equation; Transistor $T_2$ has the following data

Bfr 90 NPN – Silicon High voltage low noise for CATV, MATV

$Vcc$ = 12 volts; $Vce$ = 0.7, $Ic$max = 50 mA, $Vc$ = 6 volts, $hfe$ = 70

Max.Freq. 6GHz

Hence,

$$I_B = \frac{Ic}{hfe} = \frac{50 \times 10^{-3}}{70} = 0.00714\,A \tag{2.1}$$

$$R_{B2} = \frac{(Vcc - Vc)}{(I_c = I_B)}$$

$$= \frac{12-6}{(70 \times 0.7)mA} \tag{2.2}$$

Transposing equation (3.23)

$$R_{C2} = (Vcc - Vc)/(Ic + I_B) \tag{2.3}$$

$$= \frac{(12-6)}{0.07 + 0.000714} = 84.85\Omega \tag{2.4}$$

### 3.5 Design of Coupling Capacitors

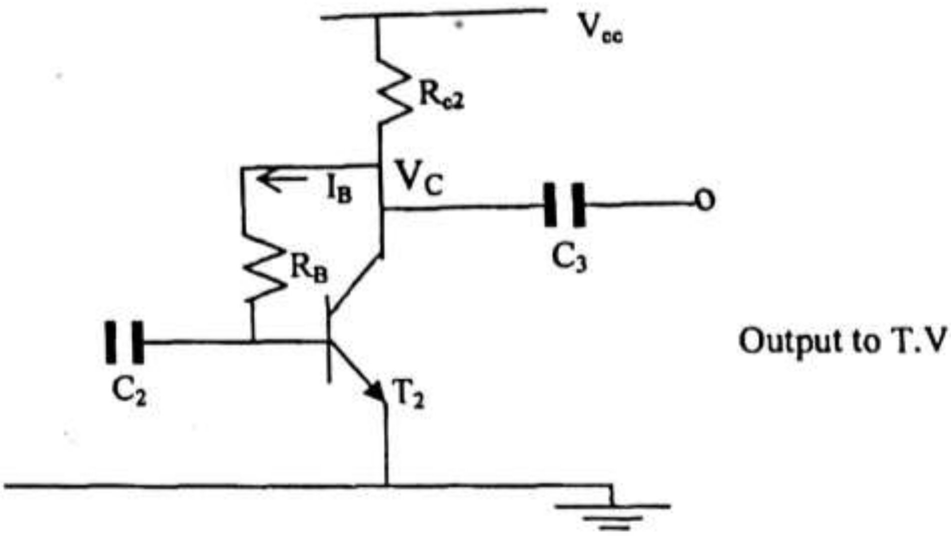


**Figure 5** : Output Stage Showing Coupling Capacitors

Capacitors are approximated as short circuits for ac signals and open circuits for dc signals. In figure 6, $C_2$ and $C_3$ are coupling capacitors; coupling capacitors are used to block the direct current yet allows the ac signal to pass.

$C_2$ thus acts as an open circuit stopping the dc of the first stage from entering with the second stage of the amplifier.

So $C_2$ is a capacitor whose reactance $Xc = 75\Omega$ ; frequency $f = 100\text{MHz}$

$$Xc = \frac{1}{2\pi fc} \tag{2.5}$$

$$C_3 = \frac{1}{2 \times \pi \times 100 \times 10^6 \times 75} = 0.2\,pF \tag{2.6}$$

For practical purposes $C_2 = 102\mu F$ was used.

### 3.6 By-Pass Capacitors For Stability

This design capacitor by pass are used to prevent any output ac or radio frequency (R.f) signal from travelling back to the input circuit. These by-pass capacitors are given as $C_4$, $C_5$ and $C_6$ in the circuit diagram of figure 7

The following values were chosen for the coupling and by-pass capacitors.

$C_2 = C_3 = 102\ \mu F$; $C_4 = C_5 = C_6 = 0.01\ \mu F$

Standard references were used as a guide for choosing these capacitor values.

**Wideband Response Circuit**

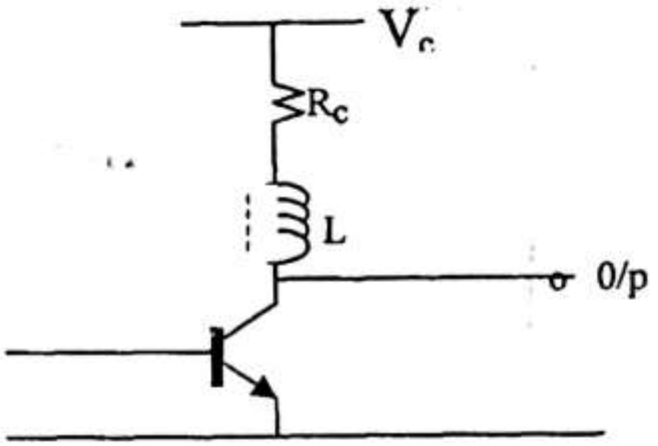


**Figure 6 :** Wide Band Response Circuit

This value of $L$ usually lies in the range of microhenry and milihenry.

$C_0$ is assumed a large value of 10pico farad, working in a choice frequency of 100MHz we have;

$$Xc = 1/2\pi f C \quad (2.7)$$

For $C = 10 \times 10^{-12}$

$$Xc = 1/(2 \times 3.142 \times 100 \times 10^6 \times 10 \times 10^{-12}) = 159.15$$

$$X_C = X_L \quad (2.8)$$

$$X_L = 2\pi f L \quad (2.9)$$

$$L = X_L/2\pi f = 159.15 / 2 \times 3.142 \times 10 \times 10^6 = 25.3 \text{ microhenry}$$

Finally choice of $L$ is usually made by experiment.

The inductor is to be wound manually on an air core;

Wheelers formulae gives that;

$$\left.\begin{array}{l} \text{Inductance} = r^2 \times N^2/9r + 10L \\ \text{Where; } r = \text{ radius of wire} \\ N = \text{ no. of turns and } \; L = \text{ length of turns} \end{array}\right\} \text{All in inches} \quad (3.0)$$

Diameter = 4/32", $r$ = D/2 = 2/32, $L$ = 8/32"

The number of turns $N$ is given as

$$N^2 = \frac{23.5 \times (3.0625)}{3.906 \times 10^{-3}}, \qquad N = \sqrt{98} = 9.9 = 10 \text{ turns}$$

## Operational Principles Of The TV Antenna Booster

The complete circuit diagram for the television antenna booster is shown in figure 7 below.

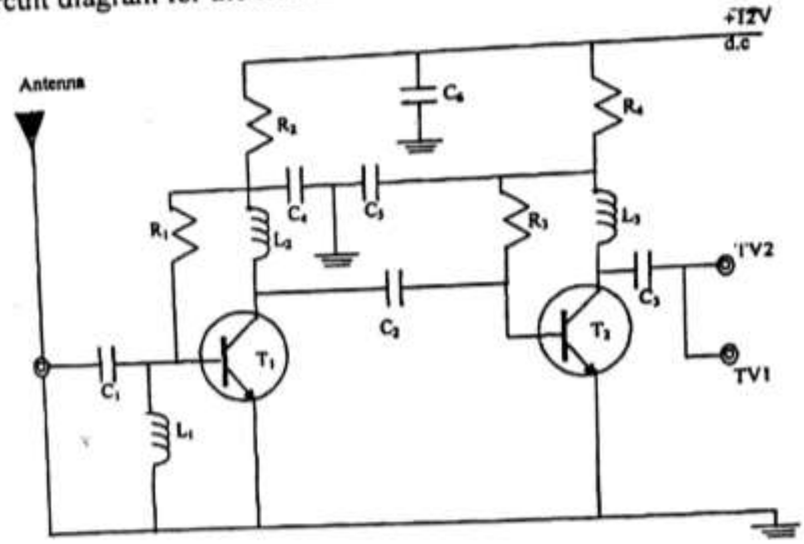


**Figure 7 :** Circuit Diagram Of TV Antenna Booster

### Operation

The Radio Frequency signal (R.F) is picked up by the antenna, this is transferred without any reflections into the amplifier by the *L*-matching circuit $C_1$ and $L_1$. The signal is then fed into the first stage of the amplifier.

This first stage is biased by $R_1$ and $R_2$ in a voltage feedback arrangement; this is to prevent thermal runaway and also to allow the emitter to be earthed directly to prevent unwanted feedback, which may affect stability of the amplifier.

The output from the first stage amplifier is coupled into the second stage amplifier by capacitor $C_2$ for more amplification of the signal. As in the first stage, Transistor $T_2$ is biased by a voltage feedback biasing utilizing resistors $R_3$ and $R_4$.

The Output from the Amplifier is coupled out to the TV receiver via Capacitor $C_2$. Capacitors are approximated as short circuits for a.c signals and open circuits for d.c signals, thus $C_2$ prevents the d.c of the first stage from interfering with the second stage d.c biasing network.

In the circuit, $C_4$, $C_5$ and $C_6$ are coupling capacitors; they act to prevent any output a.c or r.f signals from travelling back to the input circuit. They ensure the stability of the circuit, as explained by Henry (1984).

$L_1$ and $L_2$ are to increase the bandwidth of the signal; to avoid attenuation of the signal at high frequency.

Transistors $T_1$ and $T_2$ are NPN silicon transistors. NPN transistors are used because the current crossing the base region consists of electrons thus has a better high frequency response than a PNP device where holes that have a lower mobility are main carriers as explained by Connor (1992).

Two Televisions outputs are provided $T_1$ and $T_2$ for TV receivers using the coaxial cable of 75Ω terminal resistances.

### Theoretical Gain Of The TV Antenna Booster:

The Gain of the Booster is determined in terms of the circuit parameters. For common emitter amplifier as in this case;

Voltage gain is given as:

$$A_v \approx \frac{R_L // R_c}{R_e} \approx R_c / R_e \quad \text{(Martin, 1970)}$$

where;

$R_c$ = collector resistance

$R_e$ = emitter resistance

For the emitter connected directly to ground; we have $R_e \approx r_e$ (internal resistance of the emitter)

*Re* is thus; $r_e \approx 25/I_e$ (Martin, 1970)

But $I_e \approx I_c$

Thus;

$$A_v \approx \frac{R_c I_c}{25}$$

From calculated components value, this will give a gain of 35.0dB

### Performance Evaluation:

The TV antenna Booster was put in use in a rural centre where we have weak signals for both UHF and VHF, the effect was outstanding as the weak signals picked by the antenna received a significant boost giving a clearer TV reception. Noticeable too is the absence of "ghost" images, which are a clear indication of mismatch between either the antenna and the Booster or the Booster and the TV set. Clear undistorted images were observed upon testing.

### Conclusion

The television antenna Booster is a small device of low price. Its use will sure bring succour to areas (mostly rural) where there are weak television signals. With weak signals picked up by the TV antenna, a good reception can still be enjoyed. This TV antenna booster find wide application in Hotels, Establishments and large buildings where one antenna is to be used for several television sets.

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