Development of 50dB Yagi-Uda Antenna for Effective Communication.

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ABSTRACT

Fast improvements in information dissemination through communication networks have brought about the information super highway (network system), which has helped broadcasting stations; whereby any transmission from a remote area can be relayed through an antenna to any part of the world. Although, some broadcasting stations operate effectively and have wide coverage areas, some stations can hardly be received even within their home state, not to mention outside the state. However, one of the problems attributed to television transmission is the attenuation of signal with distance from the transmitting source. To reduce this effect a very sensitive and high gain antenna has to be installed with home T.V. sets to improve the reception in fringe areas where the signal strength is too weak to give clear reception. A good antenna should provide high gain and low noise. Hence, this write-up is to develop a 50dB Yagi-Uda antenna for T.V. viewers at fringe areas, which will strengthen the transmitted signal at their locations.

(Keywords: electromagnetic waves, radiation, gain, dipole, reflector, frequency, wavelength, directivity, optimization, signal strength, television, T.V., broadcasting)

INTRODUCTION

Communication and information dissemination plays a vital role in human life. Speech and music are transmitted directly from their sources to listeners across short distances by means of acoustic waves. A picture is similarly transmitted directly by optical waves across a short distance. Over long distances, wire and radio communications are used to transmit the signals and it is the special circuit component called the "antenna" which has made the radio communications possible in practice.

An antenna is a metallic structure used to convert high frequency current to electromagnetic waves, and vice versa. Electromagnetic waves are the energy sustained in space by electricity and magnetism, which propagate according to light laws [1].

One of the problems attributed to television transmission is the attenuation of the signal with distance from the radiating source. To reduce this effect there is a need to install an antenna that would possess the following characteristics such as:

- High Sensitivity
- A very high gain
- Ease and low cost of construction accessible and obtainable by the common man to give a clear reception, especially in fringe area, Hence, one of the antenna that possessed those characteristics in the Yagi-Uda antenna.

Consequently, the design of a 50dB Yagi-Uda antenna is needed to minimize the effect of those factors, which may serve as an obstacle to the flow of the wave. This antenna is applicable at higher frequencies, particularly as a U.H.F and V.H.F. television–transmitting/receiving antenna [10].

Problem Definition

Some broadcasting stations operate effectively and have wide coverage areas but it has been observed that T.V. signal viewers living in some parts of the country do not receive faithful signals transmitted into the troposphere from transmitting stations because of the distance and physical conditions like mountains, cliffs, climate, or weather conditions as well as the time of the day.

Ever since the advent of special program transmissions from far away transmitting stations, it has been realized that there is a need to improve the gain and reduce the noise levels of the signals in order to annul the adverse consequence of fading while vital programs are being relayed to space from the transmitting end. To minimize this effect, a very sensitive and powerful high gain antenna has to be installed on T.V. sets to improve the reception of signals in fringe areas in order to give clear reception.

Motivation

Yagi antennas are common everywhere, both in rural and urban areas, but most were able to achieve their goal with the aid of an electronic amplifier (booster) coupled with them. But what would happen if a government policy stops the importation of these systems into the country? Is it possible to improve the level of a signal without the use of an electronic amplifier? Therefore, there is need to design an antenna, which will not rely on an electronic amplifier.

Relevance of the Antenna

The importance of developing of the Yagi-Uda array antenna is in two-fold namely:

- To couple to space the output of a transmitter of the input of a receiver.
- To increase the level of electromagnetic wave at a particular place.

Objective of the Antenna

The main focus is on how to reduce the noise level and improve the gain of the antenna in fringe areas to produce faithfully,

- The shape of an objective (structure),
- Relative brightness of the object,
- The sound ,
- The motion, and
- The color of the object

Description of the Antenna

A Yagi antenna, is a unidirectional antenna commonly used in the HF (3 – 30MHz), VHF (30 – 300MHz) and UHF (300 – 3000MHz) bands for,

- High-gain (12dBi) but narrow bandwidth
- Modest gain (4–6dBi) but much wider bandwidth (T.V receiving antennas)

The Yagi antenna not only has unidirectional radiation and response pattern, but it concentrates the radiation and response [11]. It consists of a driven element "dipole" (i.e., a conductor half-wavelength with 75 Ohms impedance (simple dipole) or 300 Ohms impedance (double dipole) of dimension L), a reflector of dimension L_R, and a number of directors of dimension L_D. The spacing between the reflector and driven element is S_R. The distance between the successive directors is S_D. the reflector reflects RF energy, and directors direct RF energy [11].

A Yagi antenna develops an end fire radiation pattern. For optimum gains the reflector and driven elements are spaced 0.15 to 0.25 wavelengths, director-to-director spacing is 0.25 to 0.354 wavelengths apart [2].

Reflector length is typically 0.5 wavelengths to 1.05 that of the driven element. The driven element is calculated at resonance without the presence of parasitic elements. The directors are 10 to 20**%** shorter that driven elements at resonance. It consists of a driven element and one or more parasitic elements. They are arranged collinearly and close together, as shown in Figure 1 [2].

TYPICAL DESIGN PROCEDURE

Yagi-Uda Antenna Design Parameters

The typical design parameters of both UHF and VHF channels are given in Table 1 [1].

Remark: What is really wanted is that field strength in the main beam is larger than a critical minimum value.

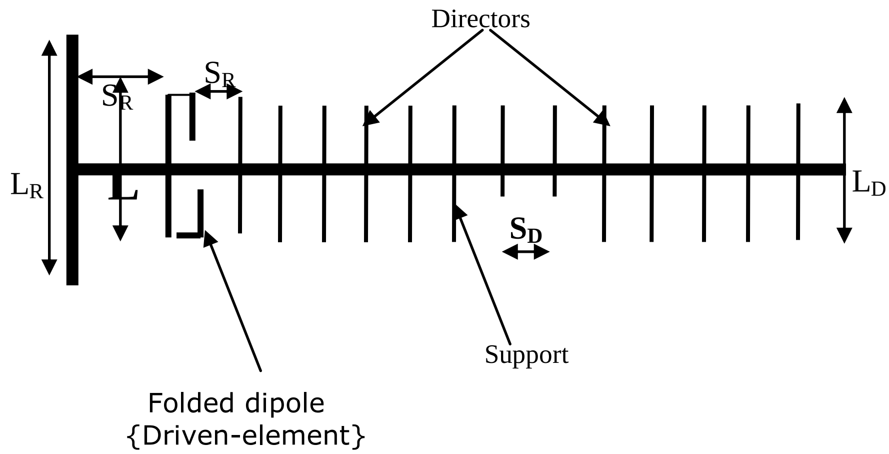

Figure 1: Plan View of Yagi-Uda Antenna.

Table 1: Design Parameter.

Number of Elements	Lengths of Reflector (L_R) (m)	Lengths of feeder (L) (m)	Lengths of Director (L_D) (m)	Spacing of Reflector (S_R) (m)	Spacing of Director (S_D) (m)
20	0.51λ	0.5 λ	0.456 λ	0.25 λ	0.15 λ

These require:

- That the directivity be larger enough over the whole frequency band.
- That the antenna's input impedance match to the generator reasonably well over the whole band.

If the impedance of the antenna matches the generator reasonably well then the VSWR will be small.

Together, these conditions should lead to sufficiently high field strength at the receiver over the whole frequency band.

Let us consider Osun State Broadcasting Corporation Ile Awiye, Oke-baale, Osogbo (OSBC) and NTA Ibadan as case studies**.**

For UHF channel, the transmitter of OSBC operates on channel 32, (578 - 584) MHz while that of VHF channel, the transmitter of NTA operates on channel 9, (186-192) MHz.

From design-calculated values, the design dimensions for both VHF and UHF antennas are tabulated as shown in Table 2.

For maximum gain, the length of the directors is critical and as the frequency changes the directors become the "wrong" length in wavelength and the gain decreases because the director length and spacing have a strong effect on [6]:

- The forward gain
- The backward gain
- The input impedance

The radiation characteristics of the array can be adjusted by controlling the geometrical parameters of the array to optimize the directivity. The very high gain 20-elements antennas are particularly recommended for reception in fringe areas because the more directors a Yagi had the greater the so-called forward-gain [3].

Firstly, the spacing between directors was varied while holding the reflector–exciter spacing and lengths of all elements constant. The results of the adjustment are shown in Table 3.

Moreover, all the spacing varying while maintains constant all the lengths parameters. The results were shown in Table 4.

Another optimization procedure is done by maintaining the spacing between all the elements constant and varies the lengths so as to optimize the directivity. The results of a 20-elements array are shown in Table 5.

The test arrangement is illustrated as shown in Figure 2. In all, improvements in directivity and front-to-back ratio are noted. Table 6 shows the combined/final results of the test carried out with the highest gain achieved.

Table 2: Design Calculated Values.

	L_R(cm)	L (cm)	L_D (cm)	S_R (cm)	S_D (cm)	Tube diameter (cm)	Boom length (m)
VHF-Antenna	80.95	79.4	73.8	39.7	23.8	0.95	4.68
UHF - Antenna	26.3	25.8	23.6	12.9	7.7	0.3	1.52

Table 3a: Directivity Optimization for 20-element Yagi-Uda Array for UHF - Band (Perturbation of all element spacing except S_{D21}), $\mathbf{L_R = 0.5\lambda, L_{D1} = L_{D2} = \ldots\ldots\ldots\ldots = L_{D18} = 0.4565\lambda}$ **r = 0.15cm.**

	S_{D21} {cm}	S_{D32} {cm}	S_{D43} {cm}	S_{D54} {cm}	S_{D65} {cm}	S_{D76} {cm}	S_{D87} {cm}	…… {cm}	S_{D2019} {cm}	Directivity {dB}
Initial array	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	12.5
Array after spacing	7.7	8.0	8.2	8.1	8.2	8.4	8.2	8.2	8.2	12.8

Table 3b: Directivity Optimization for 20–element Yagi-Uda Array for UHF - Band (Pertubation of all element spacing except S_{D21}), $\mathbf{L_R = 0.51\lambda, L_{D1} = L_{D2} = \ldots\ldots = L_{D18} = 0.4565\lambda}$**, r = 0.15cm.**

	S_{D21} {cm}	S_{D32} {cm}	S_{D43} {cm}	S_{D54} {cm}	S_{D65} {cm}	S_{D76} {cm}	S_{D87} {cm}	…… {cm}	S_{D2019} {cm}	Directivity {dB}
Initial array	3.8	23.8	23.8	23.8	23.8	23.8	23.8	23.8	23.9	13.2
Array after spacing	23.8	24.1	24.0	24.1	24.2	24.2	24.2	24.2	24.2	13.4

Table 4a: Directivity Optimization for 20–element Yagi –Uda array for UHF–Band (Perturbation of all element spacing), $\mathbf{L_R = 0.5\lambda, L_{D2} =}$ **……………………= $\mathbf{L_{D18}}$ =0.4565λ, r = 0.15cm.**

	S_{D21} {cm}	S_{D32} {cm}	S_{D43} {cm}	S_{D54} {cm}	S_{D65} {cm}	S_{D76} {cm}	S_{D87} {cm}	…… {cm}	S_{D2019} {cm}	Directivity {dB}
Initial array	7.9	7.6	7.5	7.7	7.7	7.6	7.6	7.6	7.6	11.5
Array after spacing	7.7	8.2	8.4	8.4	8.4	8.4	8.4	8.4	8.4	13.5

Table 4b: Directivity Optimization for 20-element Yagi –Uda Array for UHF–Band (Perturbation of all element spacing), $\mathbf{L_R = 0.5\lambda, L_{D2} =}$ **………………= $\mathbf{L_{D18}}$ = 0.4565λ, r = 0.15cm**

	S_{D21} {cm}	S_{D32} {cm}	S_{D43} {cm}	S_{D54} {cm}	S_{D65} {cm}	S_{D76} {cm}	S_{D87} {cm}	…… {cm}	S_{D2019} {cm}	Directivity {dB}
Initial array	23.8	24.1	24.0	24.1	24.2	24.2	24.2	24.2	24.2	13.4
Array after spacing	24.0	24.4	24.3	24.3	24.3	24.3	24.3	24.3	24.3	13.8

Table 5a: Directivity Optimization for 20-element Yagi-Uda Array for UHF – Band (Perturbation of all element lengths), $\mathbf{S_{D21}}$ **= 7.7cm, ……= $\mathbf{S_{D2019}}$ = 7.7cm, r= 0.15cm**

	L_R {cm}	L {cm}	L_{D1} {cm}	L_{D2} cm}	L_{D3} {cm}	L_{D4} {cm}	L_{D5} {cm}	…… {cm}	L_{D18} {cm}	Directivity {dB}
Initial array	26.3	25.8	23.6	23.6	23.6	23.6	23.6	23.6	23.6	11.6
Array after spacing	28.5	29.4	18.2	18.2	18.2	18.2	18.2	18.2	18.2	13.8

Table 5b: Directivity Optimization for 20–element Yagi–Uda Array for UHF–Band (Perturbation of all element lenghts), S_{D21} = 7.7cm, ………. = S_{D2019} = 7.7cm, r = 0.15cm

	L_R {cm}	L {cm}	L_{D1} {cm}	L_{D2} {cm}	L_{D3} {cm}	L_{D4} {cm}	L_{D5} {cm}	…… {cm}	L_{D18} {cm}	Directivity {dB}
Initial array	80.9	79.4	73.8	73.8	73.8	73.8	73.8	73.8	73.8	13.2
Array after spacing	81.2	80.2	70.7	70.6	70.6	70.6	70.6	70.6	70.6	14.0

Table 6a: Directivity Optimization for 20-element Yagi-Uda Array for UHF-Band (Perturbation of director spacing and all element lengths), r = 0.15

	L_R {cm}	L {cm}	L_{D1} {cm}	L_{D2} {cm}	L_{D3} {cm}	L_{D4} {cm}	L_{D5} {cm}	….	L_{D18} {cm}	S_{D2} 1	S_{D3} 2	S_{D2} 019	DIRECTIVITY {dB}
Initial array	26.3	25.8	23.6	23.6	23.6	23.6	23.6	23.6	23.6	7.7	7.7	7.7	11.6
Array after spacing perturbation	26.3	25.8	23.6	23.6	23.6	23.623.6	23.6	23.6	23.6	7.7	7.7	7.7	13.5
Optimum array after spacing and length perturbation	28	29.5	18	18	18	18	18	18	18	7.7	7.7	7.7	14

Table 6b: Directivity Optimization for 20-element Yagi- Uda Array for UHF-Band (Perturbation of director spacing and all element lengths), r = 0.15.

	L_R {cm}	L {cm}	L_{D1} {cm}	L_{D2} {cm}	L_{D3} {cm}	L_{D4} {cm}	L_{D5} {cm}	….	L_{D18} {cm}	S_{D2} 1	S_{D3} 2	S_{D2} 019	DIRECTIVITY {dB}
Initial array	80.9	79.4	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	13.2
Array after spacing perturbation	80.9	79.4	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	13.1
Optimum array after spacing and length perturbation	81.2	80.0	70.4	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	70.5	15.8

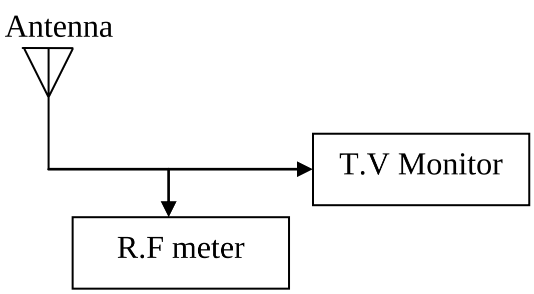

Figure 2: Testing Arrangement.

These show that the maximum gain for UHF – antenna is 14 dB and that of corresponding VHF-antenna is 15.8dB.

For maximum gain, it is better to use a stack of two or more Yagis instead of adding more directors to make a very long Yagi. An "array" of two or more Yagis gives better control of side lobe levels than a single very long Yagi.

The gain (A) of an antenna is expressed as:

$$A = 20 \log (V_o/V_1) \quad \textbf{(1)}$$

When substitute for these value in A (dB) = 20 log (V_o/V_1) this implies that sixty-four of this antenna in case of UHF antenna has to be coupled together in series in order to have a very high gain of 50dB and that of VHF antenna must be equal to fifty-two, and therefore a higher gain and a better protection against possible disturbance.

The recommended distance between two superposed antennas is about one wavelength [1].

CONSTRUCTION MATERIALS FOR THE ANTENNA

The following materials were needed for the construction of this Yagi-Uda antenna.

1. Aluminum Rod: This is needed for the construction of the reflectors, driven elements (dipoles), and directors.

***Why Aluminum*?** It is true that Yagi-Uda antenna can also be constructed with other materials like copper and steel, but the choice of aluminum material for this particular project is base on the following objectives:

- It is necessary to prevent corrosion over the antenna surface, which could result in deformed antenna surface and hence produce inadequate reflections, radiation and loss of signal at the driven element.

- It is also desired to have a very lightweight antenna so that the weight of the aerial should not supersede the stand of the mast (support).

2. Square Hollow Pipes: These were needed for the construction of the antenna frame (segment support).

3. Other materials needed include bolts, nuts, and paint.

CONCLUSION

In conclusion, the design of a 50dB Yagi-Uda antenna that was not dependant on an electronic booster was successfully carried out. This brought about the use of local source materials that can easily be available at low cost for production of the system.

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