DOI 10.30898/1684-1719.2020.3.10

ANALYSIS AND DESIGN OF 10-ELEMENT YAGI-UDA ANTENNA

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The paper is received on February 28, 2020

Abstract: A Yagi-Uda antenna, commonly known as a Yagi antenna, is a directional antenna consisting of multiple parallel elements in a line, usually half-wave dipoles made of metal rods. Yagi-Uda antennas consist of a single driven element connected to the transmitter or receiver with a transmission line, and additional "parasitic elements" which are not connected to the transmitter or receiver, a so-called reflector and one or more directors. The reflector element is slightly longer than the driven dipole, whereas, the directors are a little shorter. The main aim of the this paper is to come up with a 10-element Ultra High Frequency(UHF) aerial with optimal spacing that gives clear TV reception. A Yagi antenna is chosen for this study due to its high directionality, broadband capability, high gain and the availability of materials locally. An attempt is made to simulate the entire antenna and test it on a Samsung TV set.

Keywords: Yagi-Uda; 10-element; design.

1. Introduction

Yagi-Uda antenna is a parasitic linear array of parallel dipoles (see Fig 1), one of which is energized directly by a feed transmission line while the other act as parasitic radiator whose currents are induced by mutual coupling. The basic antenna is composed of one reflector (in the rear), one driven element, and one or more directors (in the direction of transmission/reception). The Yagi-Uda antenna has received exhaustive analytical and experimental investigations in the open literature and elsewhere. The characteristics of a Yagi antenna are affected by all of the geometric parameters of the array. Usually Yagi-Uda arrays have low input impedance and relatively narrow bandwidth. Improvements in both can be achieved at the expense of others [1,2,3].

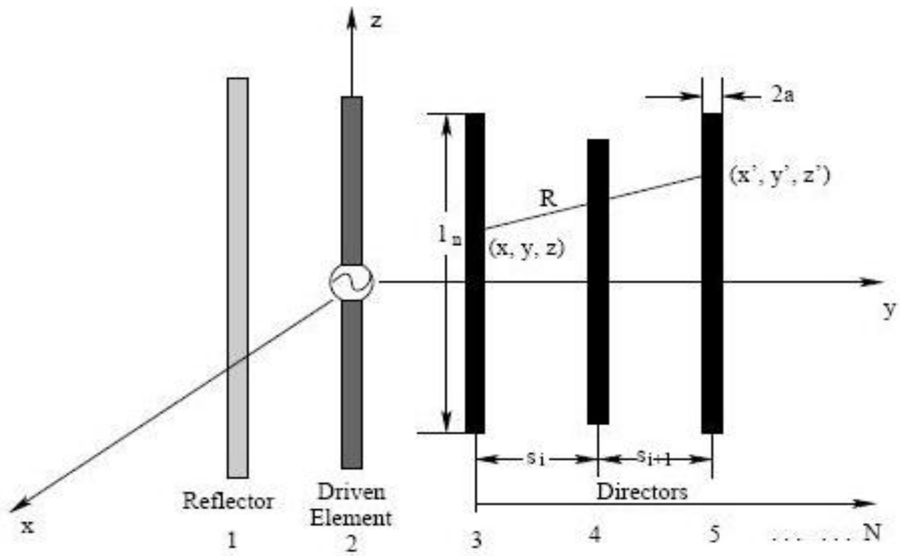

Fig.1 Geometry of Yagi-Uda array.

Often one needs to improve reception of a particular radio or television station. One effective way to do this is to build a Yagi-Uda (or Yagi) antenna because of their simplicity and relatively high gain[4,5].

The goal of the paper is to design and optimize a 10-element Yagi antenna which covers all the UHF TV channels. We choose an upper frequency of 799 MHz, mid-band frequency of 643MHz and a lower band frequency of 487 MHz, this is because the UHF TV channel starts with 487MHz and ends with 799 MHz. Antennas' gains rise slowly up to the design frequency and fall off sharply thereafter. It is therefore easier to make the design frequency a little higher than desired.

2. Construction of 10-element Yagi antenna

2.1 Dipole folding

Surprisingly, the only critical dimension seems to be the overall length (see Fig.2). The second most important dimension is probably the tubing diameter, but both of these are less critical for a folded dipole than for a plain rod dipole or Yagi directors. The spacing between the two arms of the 'trombone' can vary between quite wide limits, which is a great comfort for the designer.

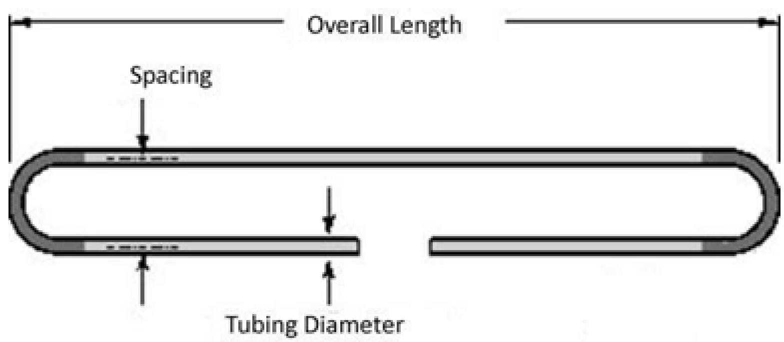

Fig.2 Element of folded dipole.

2.2 Making of bending jig

The key to good results is to invest a little time in building a bending jig. As shown in Fig.3, this can be very simple and can be made out of scrap wood. The diameter of the round former needs to be about 5mm less than the inside diameter of the bend you are aiming for, to allow for some 'spring' when bending the tubing by hand.

A good way to make the round former would be to use a metal pulley (or a wheel with the rubber tyre removed) because the groove will help to locate the tubing as you bend it. However, the former could be nothing more elaborate than a short sawn-off length of antenna mast, secured to the wooden base of the jig by a few strong nails down the inside.

The purpose of the back rail is to support the straight part of the tubing, and make sure that the bend starts with the tubing held tightly on to the former. If you are using a grooved former, you will also have to provide a packing strip to make the tubing enter the groove at the right height. It is also useful to round-off the end of the base, in case you need to use a mallet to persuade the tubing to go round the former.

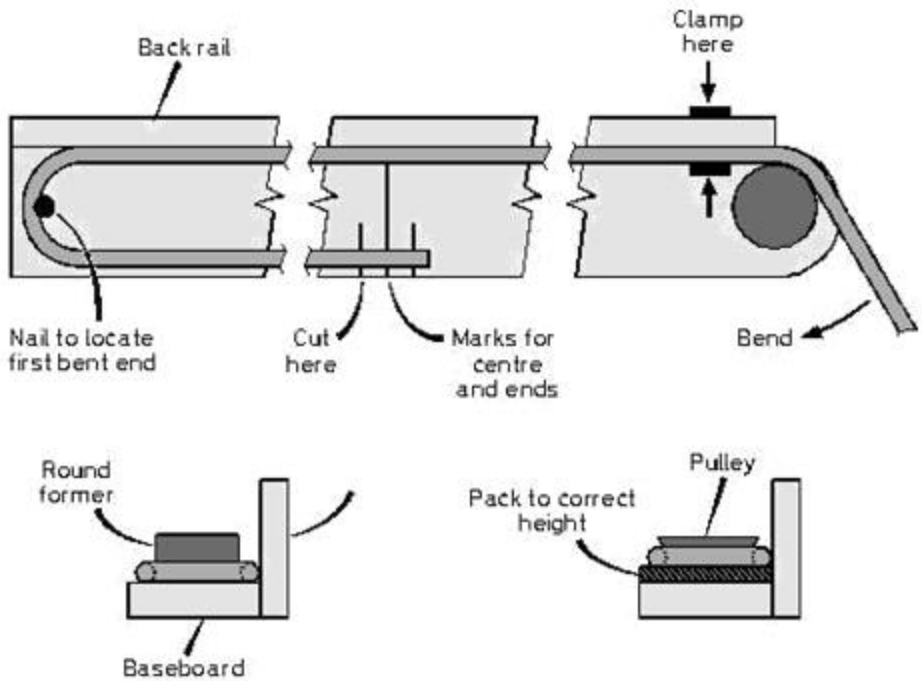

Fig.3 Making of bending jig.

2.3 Dipole enclosure and wiring

For the enclosure, a plastic circular conduit is used to create housing for the dipole ends. The center of a dipole is a relatively low-impedance area, so the grade of plastic is not critical.

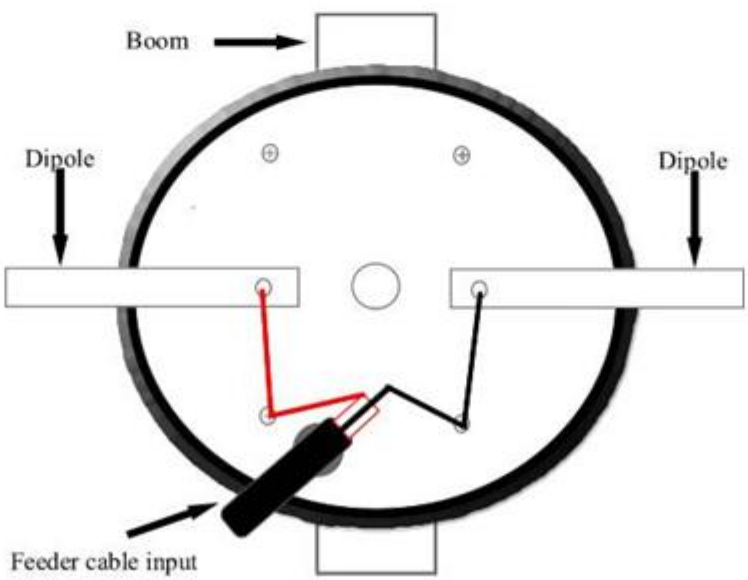

Fig.4 Wiring construction details.

Soldering of the center core of the coaxial to one of the terminals, and soldering of the braid to the other terminal are done. The dipoles are fastened to the circular conduit to make it rigid. Soldering is done as shown in Fig.4. Care is taken to ensure that the coaxial braids and the cores are kept apart to avoid short circuiting the system.

2.4 Parabolic reflector construction

Parabolic reflector diameter is 315mm. Two kinds of parabolic dishes are used: one which is plain (without drillings) and another which is perforated. The parabola is perforated to increase the front to back ratio of the antenna system. There is no particular order in which the perforations are done nor are the hole diameters significant for our study. A comparison is to be done with a plain parabolic dish to compare the effects on the forward gain of the antenna. This is illustrated in Fig.5.

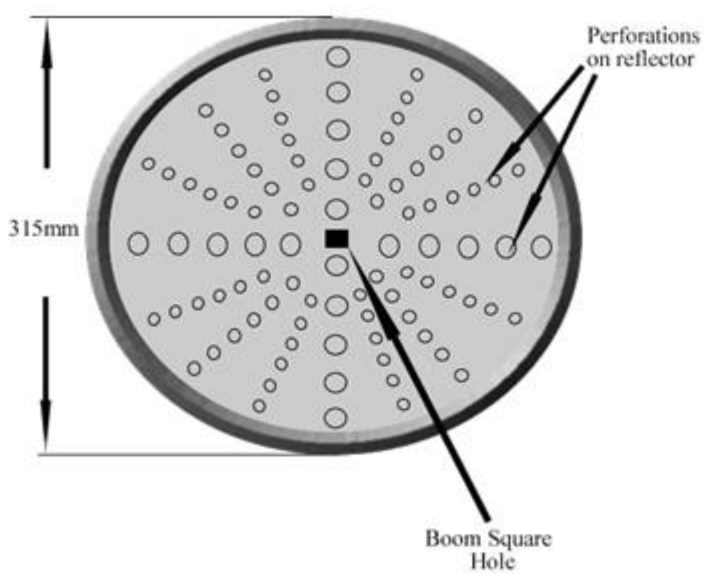

Fig.5 Perforated parabolic reflector.

2.5 Insulation

Plastic insulations are used to prevent boom from coming into contact with the dipole and the directors. Without them, there would be conductivity in the boom of the antenna which would make the polar diagrams very noisy and difficult to interpret. Fig.6 shows the insulation type that is tailor made to suit the antenna specifications.

Some force has to be employed in fitting the directors and the boom into the insulator since they did not have a perfect finish.

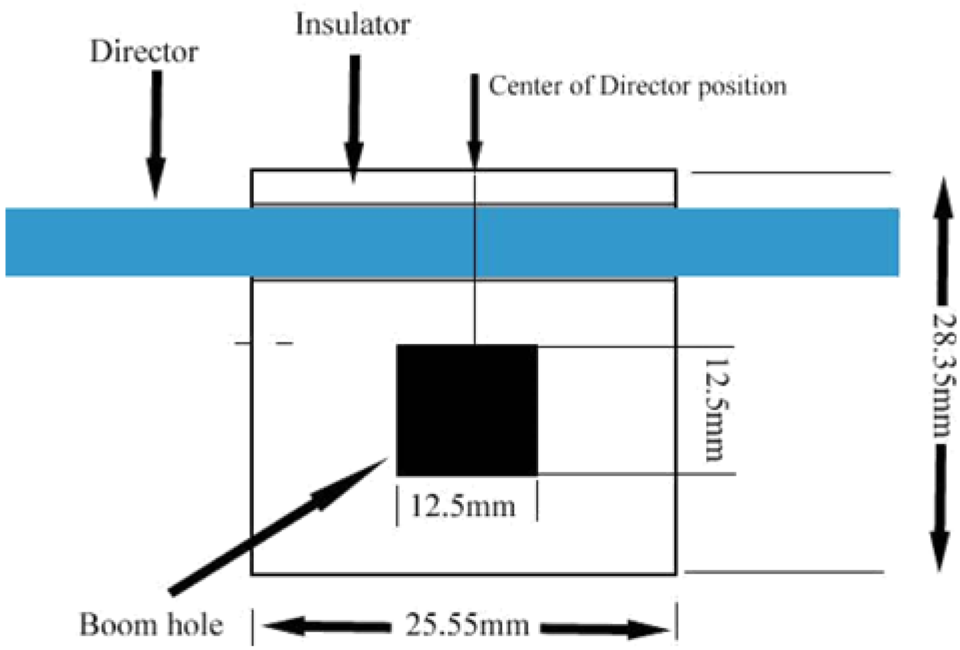

Fig.6 Plastic insulator for the dipole and boom.

3. Simulation results

Using the calculated director lengths and the table of different spacings, the following simulations are carried out using the program EZNEC-Demo-V5.0.

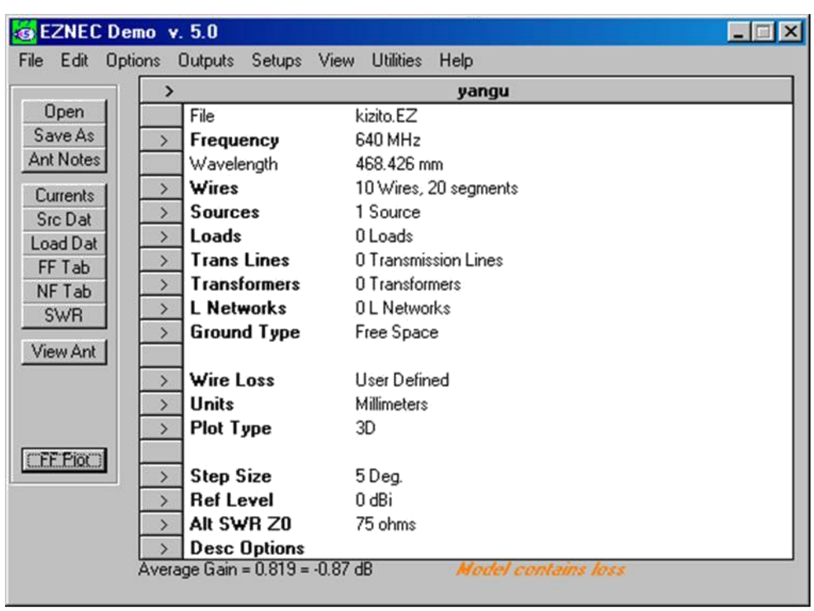

Fig.7 Full description of the antenna.

The parameters are loaded into the program and the simulation is done. The window giving the description of the Yagi antenna and its various properties is shown in Fig.7.

The window required to input the element lengths and spacing is shown in Fig.8.

Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation

Wires												
No.	End 1				End 2				Diameter	Segs	Insulation	
	X (mm)	Y (mm)	Z (mm)	Conn	X (mm)	Y (mm)	Z (mm)	Conn	(mm)		Diel C	Thk (mm)
1	0	-157.5	0		0	157.5	0		6	2	1	0
2	77	-117	0		77	117	0		7.45	2	1	0
3	140.1	-89.15	0		140.1	89.15	0		6	2	1	0
4	248.9	-89.15	0		248.9	89.15	0		6	2	1	0
5	353.3	-89.15	0		353.3	89.15	0		6	2	1	0
6	449.7	-89.15	0		449.7	89.15	0		6	2	1	0
7	543.5	-89.15	0		543.5	89.15	0		6	2	1	0
8	631.9	-89.15	0		631.9	89.15	0		6	2	1	0
9	711.7	-89.15	0		711.7	89.15	0		6	2	1	0
10	789.1	-89.15	0		789.17	89.15	0		6	2	1	0
*												

Fig.8 element lengths and spacing.

The antenna is depicted from the data given as shown in Fig.9.

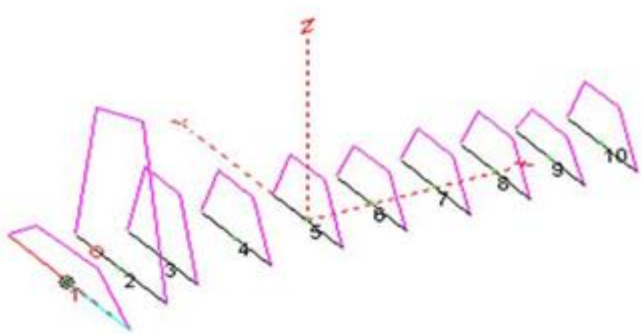

Fig.9 10-element Yagi antenna simulation.

3.1 Radiation patterns

3.1.1 Azimuth plot

The azimuth plot pattern is shown in Fig.10, while, Table 1 shows the various parameters of the azimuth plot.

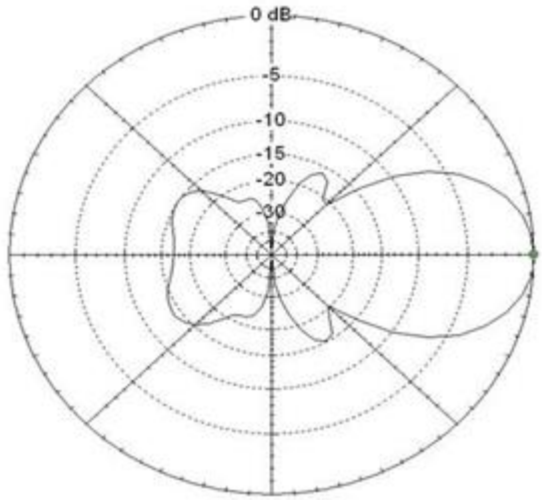

Fig.10 Azimuth plot pattern.

3.1.2 Elevation type plot

Table 1. Various parameters of the azimuth plot.

Elevation angle	0.0 deg
Outer Ring	9.97 dBi
3D Max gain	9.97 dBi
Slice Max gain	9.97 dBi @ Az angle = 0.0 deg
Front/Back	18.36 dB
Beamwidth	43.1deg; -3dB @338.5, 21.6 deg
Sidelobe gain	-4.19 dBi @Az angle=215.0 deg
Front/Sidelobe	14.16 dB

The elevation type plot is shown in Fig.11, while, Table 2 shows elevation slice parameters.

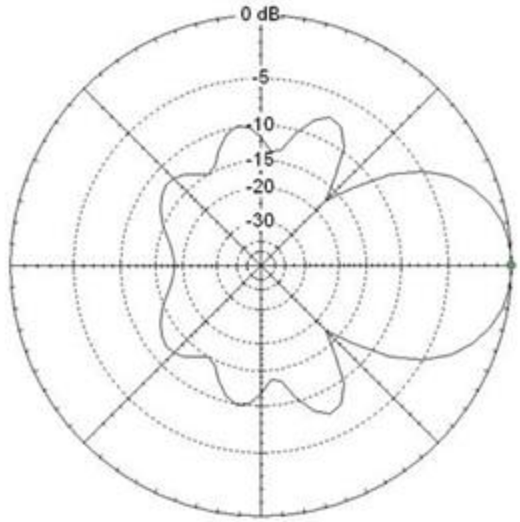

Fig.11 Elevation type plot.

Table 2. Elevation slice parameters.

Azimuth angle	0.0 deg
Outer Ring	9.97 dB
3D Max gain	9.97 dB
Slice Max gain	9.97 dBi @Elev angle=0.0 deg
Front/Back	18.36 dB
Beamwidth	49.36 deg; -3dB @335.2, 24.8 deg
Sidelobe gain	2.6 dB i@Elev angle=65.0 deg
Front/Sidelobe	7.37 dB

The three dimensional(3D) plot of the azimuth is shown in Fig.12.

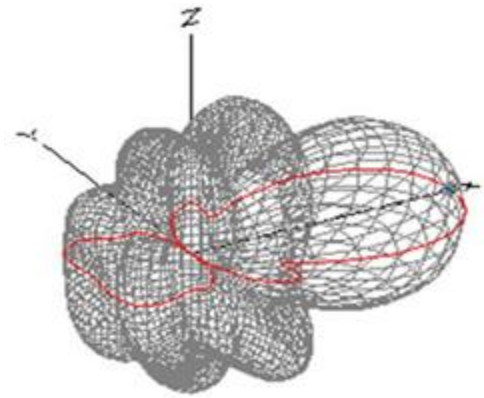

Fig.12 3D azimuth plot.

3.2 Standing wave ratio(SWR)

Using a 75 ohm coaxial line feed and a frequency range from 487 MHz to 799MHz, SWR plot is obtained as shown in Fig.13. Under normal analysis, the SWR is chosen for the center frequency of the antenna in question. From the graph, we can deduce that at 640 MHz, the SWR is approximately 1.8.

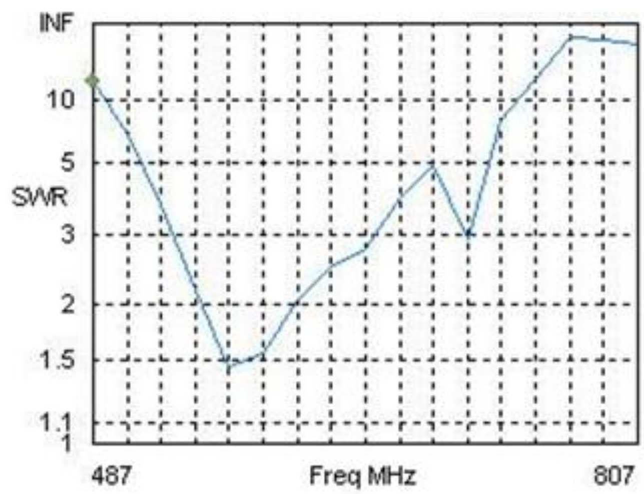

Fig.13 SWR plot.

3.3 Testing on Samsung TV set

Our paper has involved the research, design and simulation of a 10 element Yagi antenna which is successful when tested on a Samsung TV set. All channels are found to give clear reception.

4. Conclusion

Yagi-Uda antennas play an important role in various modern wireless communication technologies, because of their properties like low cross polarization level, moderate gain and high radiation efficiency. In this paper, A 10-element Yagi antenna was successfully designed and simulated. The simulation results coincided with the theoretical results. The antenna was successfully tested on Samsung TV set.

References

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For citation:
Abdulhamid M. Analysis and design of 10-element Yagi-Uda Antenna. *Zhurnal Radioelektroniki - Journal of Radio Electronics*. 2020. No. 3. Available at http://jre.cplire.ru/jre/mar20/10/text.pdf.
DOI 10.30898/1684-1719.2020.3.10