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School of Electronics Engineering (SENSE)

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ABSTRACT:

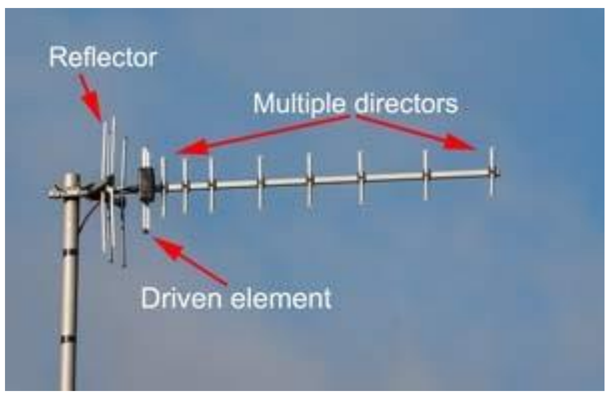
This antenna will extend the range of your Wi-Fi or 2.4GHz devices (like surveillance cameras) into many miles and kilometers. A Yagi antenna is basically a telescope for radio waves. The Yagi antenna has 20 parasitic elements. This ensures it has a long-range communication , although having a long-range communication does sacrifice on beam width.

We have used a 20mm stainless steel boom, 3mm stainless steel parasitic elements, 6mm stainless steel reflector element and a 3mm copper tube for the dipole. We calculated the values to get all the position for all the elements of the antenna.

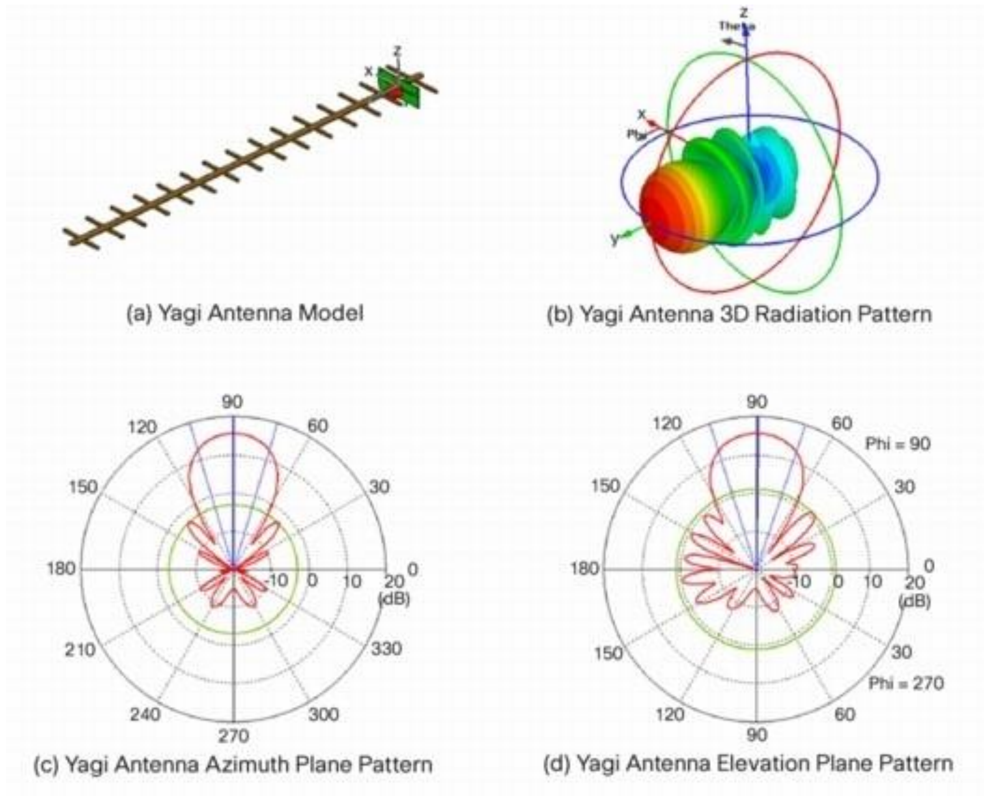
INTRODUCTION:

What is a Yagi Antenna?

A Yagi antenna or a Yagi-Uda antenna, is a directional antenna that radiates signals in one main direction. It consists of a long transmission line with a single driven element consisting of two rods connected on either side of the transmission line. It also consists of a single reflector on one side of the transmission line and a number of parasitic elements which act as directors. The driven element of a Yagi is equivalent of a center-fed, half-wave dipole antenna. Parallel to the driven element are straight rods or wires called reflectors and directors. A reflector is placed behind the driven element and is slightly longer than driven element; a director is placed in front of the driven element and is slightly shorter than driven element. A typical Yagi antenna has one reflector and one or more directors.

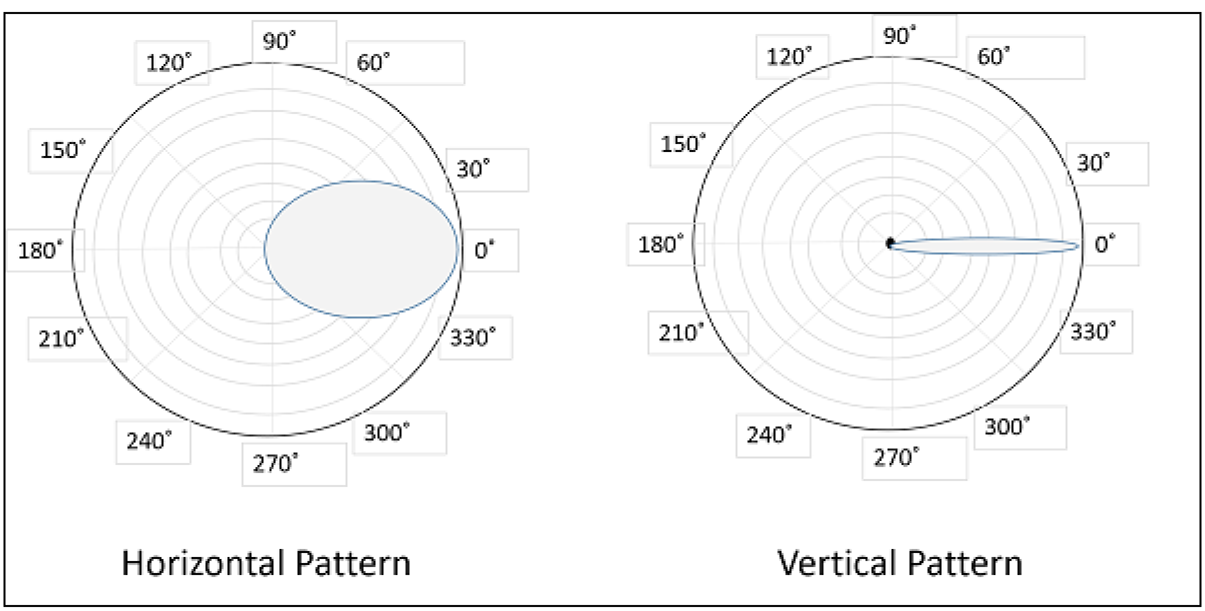


The Yagi antenna propagates electromagnetic field energy in the direction running from the driven element toward the director(s), and is most sensitive to incoming electromagnetic field energy in this same direction. The more directors a Yagi has, the greater the forward gain and the longer the antenna becomes. This type of antenna has become particularly popular for television reception, but it is also used in a number of other domestic and commercial applications where an RF antenna with high gain and directivity is needed.



Radiation Pattern:

The directional pattern of the Yagi-Uda antenna is highly directive as shown in the figure given below.



The minor lobes are suppressed and the directivity of the major lobe is increased by the addition of directors to the antenna.

Early development:

The Yagi-Uda antenna was developed by H. Yagi and S. Uda and it was published in English in the Proceedings of the Imperial Academy in Japan in February 1926 [1], until 1928 this paper was credited with bringing the concept of the Yagi-Uda antenna to the world audience. The basic Yagi-Uda array antenna consists of a parallel set of linear dipole radiators. The leftmost element is slightly larger than resonant length and is called reflector. The next element is a dipole element with a feed line. The rightmost elements are slightly less than resonant length and are called directors. The space between elements is about λ − 3.02.0 λ . In Yagi-Uda antenna, only one element is directly driven. The radiation is predominantly to the right of the array and along the axis of the antenna. Yagi-Uda antenna is easy to achieve − 2010 dBdB gains.

A conventional Yagi-Uda Array consists of a number of linear dipole element with one of these elements energized directly by a feeding transmission line while the others act as parasitic radiators whose current are induced by mutual coupling (Figure.1). The following guidelines are followed to obtained end-fire beam formation. The parasitic elements in the direction of the beam are smaller in length than the feed element (< LL dridir). As a design standard, the driven element resonates with a length less than 5.0 λ , usually from λ − 49.045.0 λ , whereas directors have lengths on the range from λ − 45.04.0 λ . The dirctor do not require all being of same length and diameter. The separation between director (Sdir) ranges from λ − 4.03.0 λ and does not need to be uniform between elements to achieve adequate operation. The length of the reflect is greater than that of the feed element (ref > LL dir). The separation between the driven element and the refector (Sref) is smaller than the spacing between the driven element and the nearest director (Sdir), presenting optional size for Sref of 25.0 λ .

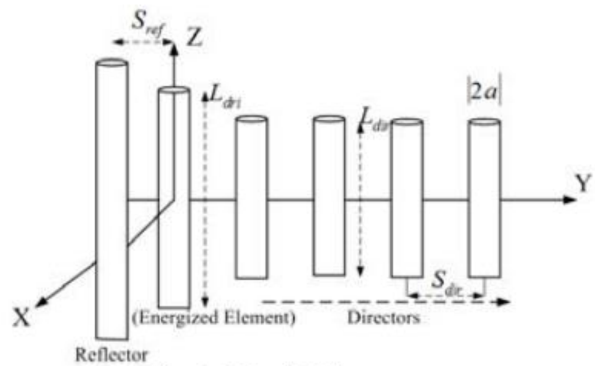


Fig. 1. Yagi-Uda antenna

The Yagi-Uda array antenna has the important practical advantage that a complex feed network is not required, only a single element is directly fed. In addition, the elements may be as simple as wires, rods or thin metallic tubes. So the Yagi-Uda array is popularly used in the application for radio beacons, radio links, and early radar systems in United States and Europe. It is ironical history in 1942, when the Japanese army invaded Singapore, they discovered that the Yagi-Uda array was being used as a radair antenna by the British army. This interesting story was told from a first-person perspective by Prof. G. Sato in [2].

Recent advances:

More recent work has shown that microstrip antennas can be configured in a Yagi-Uda configuration for low-angle satellite reception for mobile communications [3]. John Huang proposed a new antenna structure that is formed by combining the Yagi-Uda array concept and the microstrip radiator technique. This antenna, called the microstrip Yagi array antenna, is a low-profile, low-cost, and mechanically steered medium-gain land-vehicle antenna. The microstrip Yagi array antenna consists of a single driven element patch, a single parasitic reflector patch, and two or three director patches. The beam peak of this array, due to the effect of mutual coupling and Yagi-Uda principle [4], can be tilted away from the broadside direction and toward the direction of the director patches. In the microstrip Yagi array, the electromagnetic energy is coupled from the driven patch to the parasitic patches not only through space but also by surface waves in the substrate. In order for the microstrip patches to function similarly to the Yagi dipoles, the adjacent patches need to be placed very closely to each other so that a significant coupling can be obtained through surface waves in the substrate.

Although the configuration and coupling mechanism of the microstrip Yagi array and dipole Yagi antenna are different, the design rules for these two types of Yagi are very similar. Perhaps the only major problem of the entire class of antennas is their seeming inherent narrow bandwidth. The most usual method of increasing the bandwidth is simply to increase the thickness of the dielectric substrate between the radiator and the ground plane. Many techniques exhibiting significant bandwidth increase have been reported. Finally, we provide a perspective discussion of the significant chanllenges still lying ahead in this research field.

Planar structures:

The Qusi-Yagi Antenna:

Kaneda [5] proposed a coplanar-stripline-fed printed Yagi-Uda antenna with the reflector element printed on the back of a thick and low-permittivity slab at 60GHz. Some types of planar Yagi-Uda antenna that are well suited to microwave and millimeter wave frequencies. Recently, many novel uniplanar Quasi-Yagi antennas that have both the compactness of resonant-type antennas and broadband characteristics of travelling-wave radiators have been proposed. Qian et al. [6] proposed a microstrip-tocoplanar strip transition and used the truncated microstrip ground plane as its reflecting element (Fig. 2a). An X-band prototype exhibits a measured bandwidth of 17% and 6.5dB gain. Kaneda et al.[7] proposed a microstrip-to-waveguide transition utilizing coplanar strips to design quasi-Yagi antenna, and their Xband transition demonstrates about 40% bandwidth. The Yagi-Uda dipole array type of antenna is realized on a high dielectric constant substrate with a microstrip feed. Unlike the traditional Yagi dipole design, the truncated microstrip ground plane is employed as a refecting element, thus elimiting the need for a reflector dipole. This results in a very compact design ($< \lambda 0\ 2$ by $\lambda 0\ 2$), which is totally compatible with any microstrip-based MMIC circuitry. Kaneda et al. [7] presented further information on the design and performances of broadband Quasi-Yagi antenna, this antenna achieved extremely broad bandwidth (measured 48% for VSWR < 2).

Kretly et al. [8] proposed a quasi-Yagi patch antenna that consists of changing the traditional dipole driver element to a pair of planar patch elements. The patches were designed with length equal to half a dipole driver and the width equal to the length acquiring a square form. This planar quasi-Yagi antenna was demonstrated by Kretly at 2.2GHz and a squar structure with patches as driver, which achieve wide frequency bandwidth, 42%, measured at the patch driver. The antennas should have wide applications in a great variety of wireless systems, such as power combining and phase arrays.

Weinmann [9] presented a planar antenna array based on nine identical quasi-Yagi elements. Feeding networks were carefully designed in order to provide synchronized output signals over a wide frequency range. The input return loss of the antenna array is better 15dB over most parts of the relevant spectrum, with a total bandwidth of 45%. The planar antenna array is well suited as a radiating element in linear phased arrays for multifunction radars, including SAR and MTI, and other applications requiring a large scan angle. Additionally the suitability of this antenna for phased-array applications is studied by an experimental set consisting of five antenna plates. So far the printed quasi-Yagi antennas have been mostly realized on high dielectric constant substrates with moderate thickness in order to excite the TE0 surface wave along the dielectric substrate. Nasiha [10] used an additional director and a reflector was used to increase the gain of the antenna (Fig. 2b). However, the achieved bandwidth of the antenna is quite narrow (about 3-4%) compared to the bandwidth of a quasi-Yagi antenna fabricated on a high dielectric constant substrate [11]. Another disadvantage of a conventional quasi-Yagi antenna fabricated on a low dielectric constant substrate is that the length of the dirver is increased and it is difficult to achieve 5.0 $\lambda 0$ spacing between the elements required for scanning arrays, where $\lambda 0$ corresponds to a free-space wavelength at the center frequency of the antenna.

Generally, the folded dipole has better bandwidth characteristics than a single half-wavelength dipole [12] , which leads to improved bandwidth. The input impedance of an isolated folded dipole is a function of the relative width of the driven and parasitic conductors and may be varied in the range of approximately

70-280 Ω . This property gives the new element more design flexibility compared to the standard half-wavelength dipole configuration and allows the use of a wider range of characteristic impedances for the feed network. Compared to a standard half-wavelength dipole, the length of a folded dipole may be reduced by varying the width of the joining strips and therefore this element is more suitable for applications requiring arrays of closely spaced quasi-Yagi antennas. Mutual coupling between the folded dipole quasi-Yagi antennas is also shown to be low for typical element spacings.

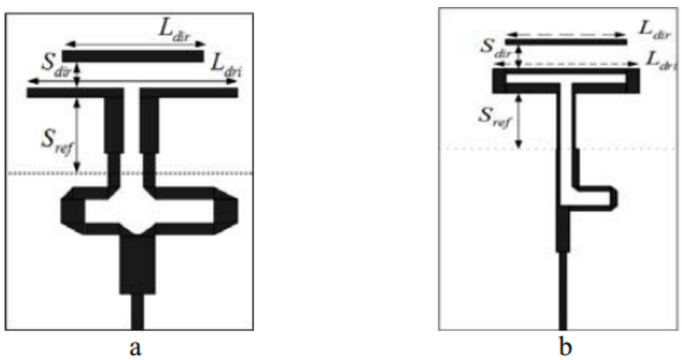


Fig. 2. (a) Schematic diagram of Quasi-Yagi antenna fed by microstrip-to-CPS transition
(b) Configuration of the folded dipole antenna

Feeding networks for quasi-Yagi antenna:

The basic Yagi antenna does not need complicated feed network and it can be directly connected to the coaxial line. The printed antennas are generally economical to produce, since they exhitit a very low profile, small size, lightweight, low cost, and high efficiency, and are easy to install. More and more planar quasi-Yagi antennas are used in RF and microwave frequencies. However, the planar quasi-Yagi antenna does not have wide bandwidth, while its improved version with modified feeding network can achieve excellent bandwidth. Kaneda et al. proposed an approach to realize a Yagi-Uda dipole array fed by a mcirostrip-to-coplanar stripline (CPS) transition on a single layer PCB substrate. Within this antenna configuration, the transition feeding network plays an important role in the overall antenna performance.

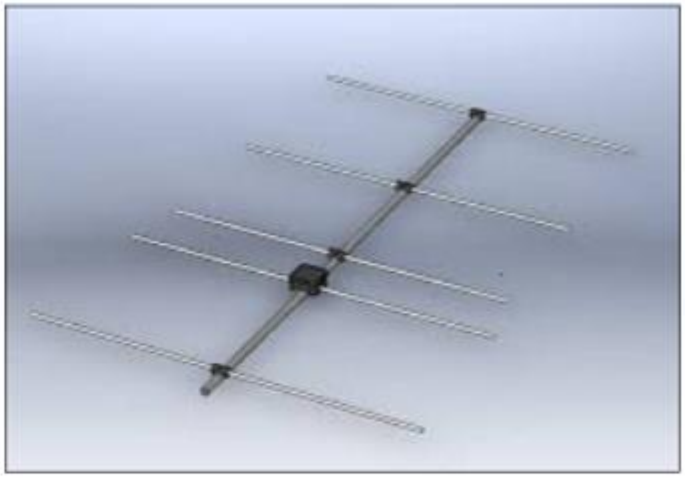
Many researchers have investigated techniques to improve the antenna's bandwidth, and reduce its size to fit in the new wireless tools, such as PDAs, cell phones, and RFID. A probe-fed E-shaped patch antenna achieved a bandwidth of more than 30% with high directivity, but the antenna itself was quite large in size and it required a much larger ground plane to suppress the backside radiation and to provide the claimed bandwidth. Very good bandwidths, ranging from 57% to 70%, were achieved in [15], [16], [17]. However, all of these antennas decreased directivity and gain. In addition, high cross polarization levels and a narrow beamwidth were produced by these antennas. Qian et al. [18] proposed an improved approach for realizing an efficient microstrip-to-coplanar strips (CPS) transition, by employing a symmetric and optimized T-junction for signal dividing/combining, and using optimal miters for 90- degree microstrip bends. The improvement in the performance of transition is significant. The 3-dB insertion loss bandwidth is measured to be 68% for a balanced back-to-back microstrip-to-CPS transition, and the VSWR is below 2 within the whole useful bandwidth. An additional advantage of this new transition is that it has simpler design criteria in comparison with previous structures because of the use of a symmetric T-junction. In [16], the developed quasi-Yagi radiator was applied to microstrip-to- waveguide transition design. A bandwidth of 35% with return loss better than 12dB has been achieved and the insertion loss is about 0.3dB at the center frequency of the X-band prototype. This quasi-Yagi antenna consists of two dipole antennas, a truncated ground plane, and a microstrip-to-CPS balun. The CPS antenna has the coupled microstrip line input. The coupled microstrip line is connected to the CPS line with different strip widths. Since the CPS line does not support the even mode, it acts as an open end for the even mode of the coupled microstrip line, and enables us to suppress the undesired mode excited in the coupled microstrip line. The CPS line is connected to the printed dipole antenna that has a length of approximately λd 2 where 2 (1) d = 0 ελλ r + and positions approximtately λd 4 away from the reflector (truncated ground plane).

In [19], Zhang et al. presented an approach of designing broadband Quasi-Yagi dipole antenna using substrate integrated waveguide (SIW) techniques. The antenna configuration involves a newly proposed broadband microstrip-to-broadside parallel stripline transition and two-element printed quasi-Yagi array. The proposed transition was constructed with the SIW scheme, which can achieve a broadband performance and offer several advantages over other counterparts, such as low insertion loss, good design tolerance and compact circuit size at the millimetre wave range. One major characteristic of the proposed transition is that the balanced line is created by geometric features, not by frequency sensitive structures. By using the proposed transition as the feeding network for printed quasi-Yagi antenna, this antenna configuration can be easily adapoted to millimetre wave applications with a conventional low-cost PCB fabrication process. The design concept has been validated by a design example for K-band operation. The measured input return loss of the Quasi-Yagi antenna is better than 10dB with an impedance bandwidth as wide as 14GHz (20GHz to 34GHz), or 51%. Finally, to further demonstrate the performance of the proposed quasi-Yagi antenna , an array has also been designed and measured.

CONSTRUCTION OF YAGI-UDA ANTENNA:

A Yagi-Uda antenna was seen on top of almost every house during the past decades. The parasitic elements and the dipole together form this Yagi-Uda antenna.

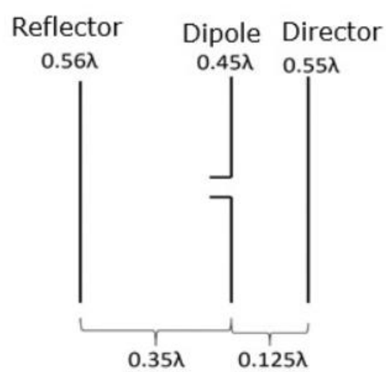
The figure shows a **Yagi-Uda antenna**. It is seen that there are many directors placed to increase the directivity of the antenna. The feeder is the folded dipole. The reflector is the lengthy element, which is at the end of the structure.



The figure depicts a clear form of the Yagi-Uda antenna. The center rod like structure on which the elements are mounted is called as **boom**. The element to which a thick black head is connected is the **driven element** to which the transmission line is connected internally, through that black stud. The single element present at the back of the driven element is the **reflector**, which reflects all the energy towards the direction of the radiation pattern. The other elements, before the driven element, are the **directors**, which direct the beam towards the desired angle.

Designing:

For this antenna to be designed, the following design specifications should be followed.



They are −

ELEMENT	SPECIFICATION
Length of the Driven Element	0.458λ to 0.5λ
Length of the Reflector	0.55λ to 0.58λ
Length of the Director 1	0.45λ
Length of the Director 2	0.40λ
Length of the Director 3	0.35λ
Spacing between Directors	0.2λ
Reflector to dipole spacing	0.35λ
Dipole to Director spacing	0.125λ

If the specifications given above are followed, one can design a Yagi-Uda antenna.

DESIGN:

Designing our antenna:
Yagi design frequency =2400.00 MHz
Wavelength =125 mm
Parasitic elements contacting a round section metal boom 20 mm across.
Folded dipole mounted same as directors and reflector
Director/reflector diam =3 mm
Radiator diam =3 mm

REFLECTOR
73.3 mm long at boom position = 30 mm (IT = 26.5 mm)

RADIATOR

Folded dipole 71.6 mm tip to tip, spaced 25.0 mm from reflector at boom posn 55.0 mm (IT = 26.0 mm)

DIRECTORS

Dir (no.)	Length (mm)	Spaced (mm)	Boom position (mm)	IT (mm)	Gain (dBd)	Gain (dBi)
1	63.8	9.4	64.4	22.0	4.8	6.9
2	63.0	22.5	86.8	21.5	6.5	8.6
3	62.3	26.9	113.7	21.0	7.8	9.9
4	61.6	31.2	144.9	21.0	8.9	11.0
5	61.0	35.0	179.9	20.5	9.8	11.9
6	60.4	37.5	217.4	20.0	10.5	12.7
7	59.9	39.3	256.7	20.0	11.2	13.3
8	59.4	41.2	297.9	19.5	11.7	13.9
9	58.9	43.1	341.0	19.5	12.2	14.4
10	58.5	45.0	386.0	19.5	12.7	14.9
11	58.1	46.8	432.8	19.0	13.1	15.3
12	57.8	48.1	480.9	19.0	13.5	15.7
13	57.4	48.7	529.7	18.5	13.8	16.0
14	57.1	49.3	579.0	18.5	14.2	16.3
15	56.8	50.0	629.0	18.5	14.5	16.6
16	56.5	50.0	678.9	18.5	14.7	16.9
17	56.3	50.0	728.9	18.0	15.0	17.1
18	56.1	50.0	778.9	18.0	15.2	17.4
19	55.8	50.0	828.8	18.0	15.4	17.6
20	55.6	50.0	878.8	18.0	15.6	17.8

COMMENTS

The abbreviation "IT" means "Insert To", it is the construction distance from the element tip to the edge of the boom for through boom mounting.

Spacings measured centre to centre from previous element
Tolerance for element lengths is +/- 0 mm.

Boom position is the mounting point for each element as measured from the rear of the boom and includes the 30 mm overhang.The total boom length is 909 mm including two overhangs of 30 mm.

The beam's estimated 3dB beamwidth is 26 deg.

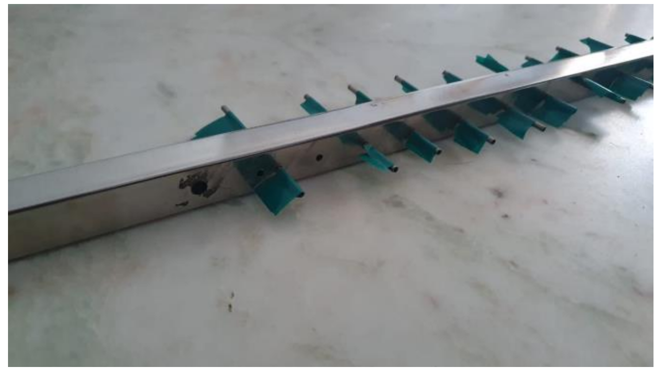
A half wave 4:1 balun uses 0.66 velocity factor RG-17A (PE) and is 41 mm long plus leads.

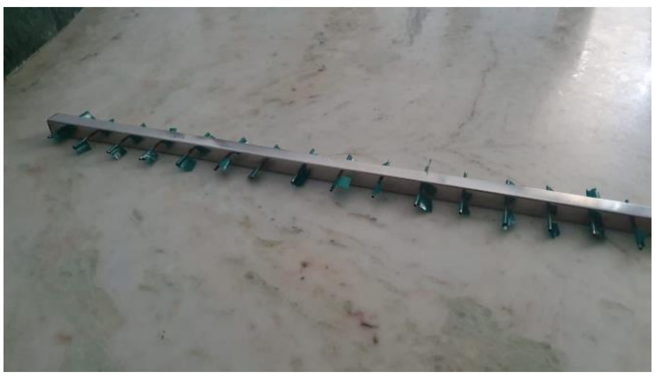
FOLDED DIPOLE CONSTRUCTION
Measurements are taken from the inside of bends
Folded dipole length measured tip to tip = 72mm
Total rod length =161mm
Centre of rod=81mm
Distance BC=CD=26mm
Distance HI=GF=23mm
Distance HA=GE=39mm
Distance HB=GD=55mm
Distance HC=GC=81mm
Gap at HG=5mm
Bend diameter BI=DF=20mm

If the folded dipole is considered as a flat plane (see ARRL Antenna Handbook) then its resonant frequency is less than the flat plane algorithm's range of 10:1

MATERIALS GUIDE for purchase. Allow extra, do NOT use these figures for cutting
NO allowance for saw cuts or purchased lengths resulting in waste
1) Length used by directors and reflector 1249.9mm of round 3mm rod
2) Length used by single dipole 56.9mm or folded dipole 161.1mm of round 3mm rod
3) Length used for boom 908.8mm (allows for 30mm each end) round stock 20mm diameter

IMPLEMENTATION (REAL TIME):





FORMULA/EQUATIONS USED IN YAGI ANTENNA CALCULATIONS:

Reflector length = $0.495 * \lambda$
Dipoe length = $0.473 * \lambda$
Director length = $0.440 * \lambda$

Reflector to Dipole spacing = $0.125 * \lambda$
Dipole to Director spacing = $0.125 * \lambda$

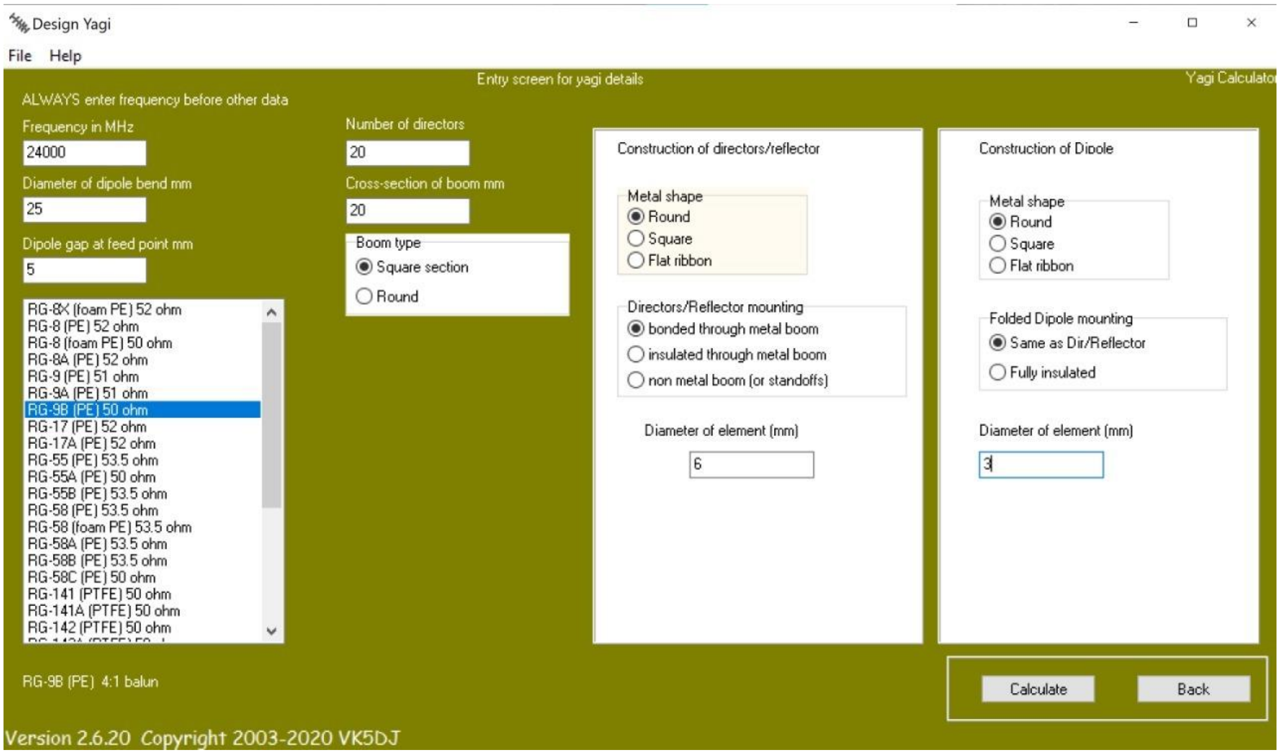
$\lambda = c/f$

λ-Wavelength in meters
c-Velocity of propagation in air(3*10^8m/s)
f-Carrier frequency in MHz

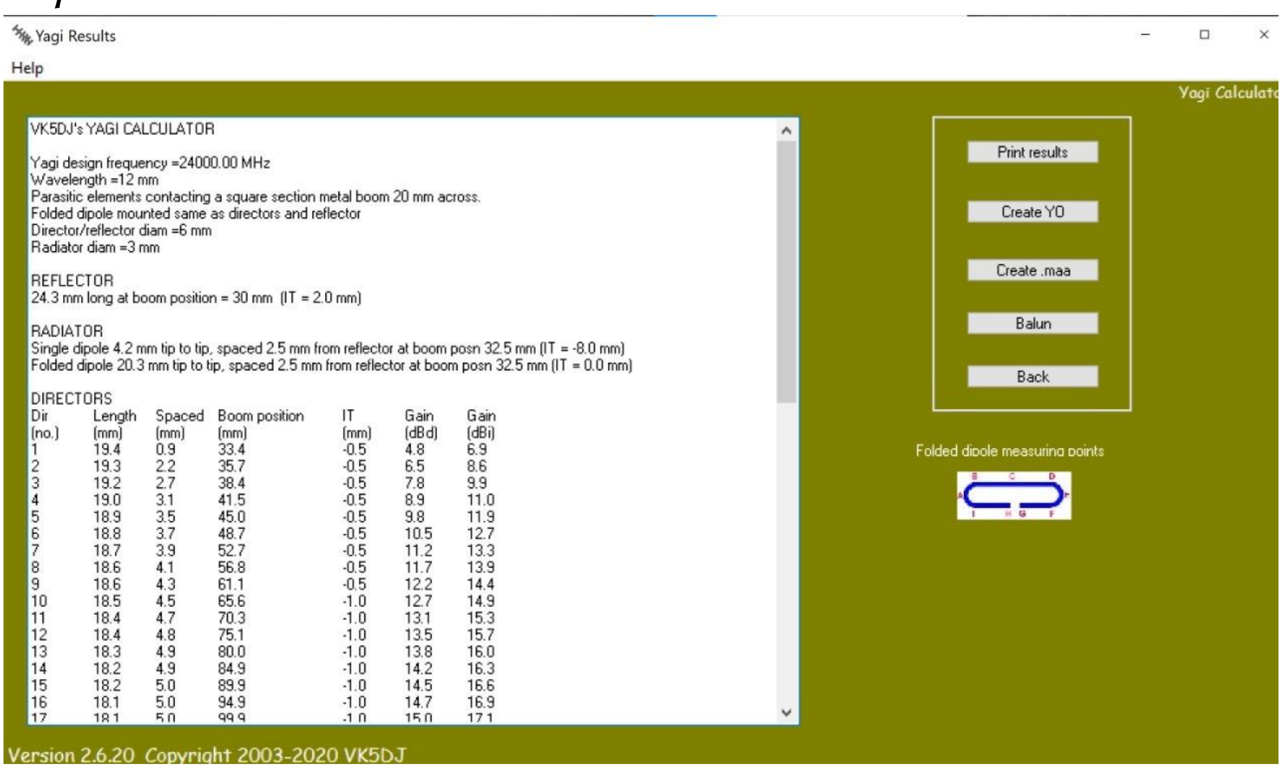
RESULTS & INFERENCES:

THEORETICAL ANALYSIS:

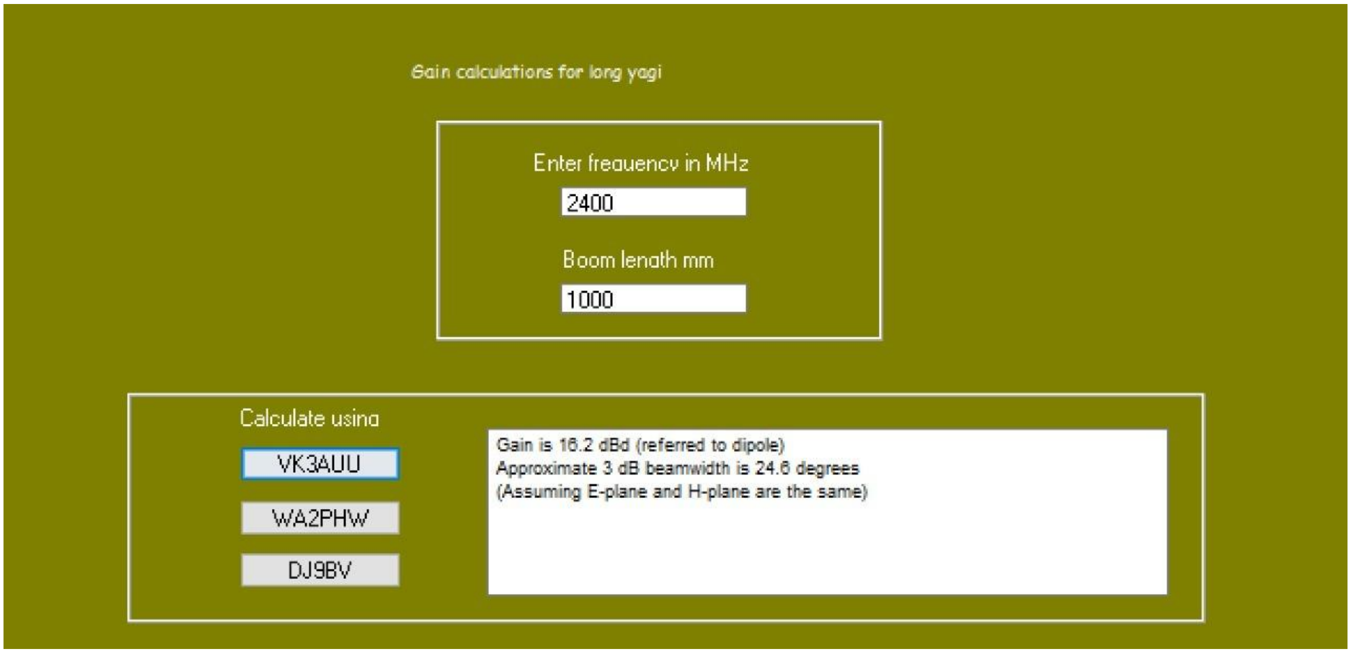
Step1: Calculating inter director measurements



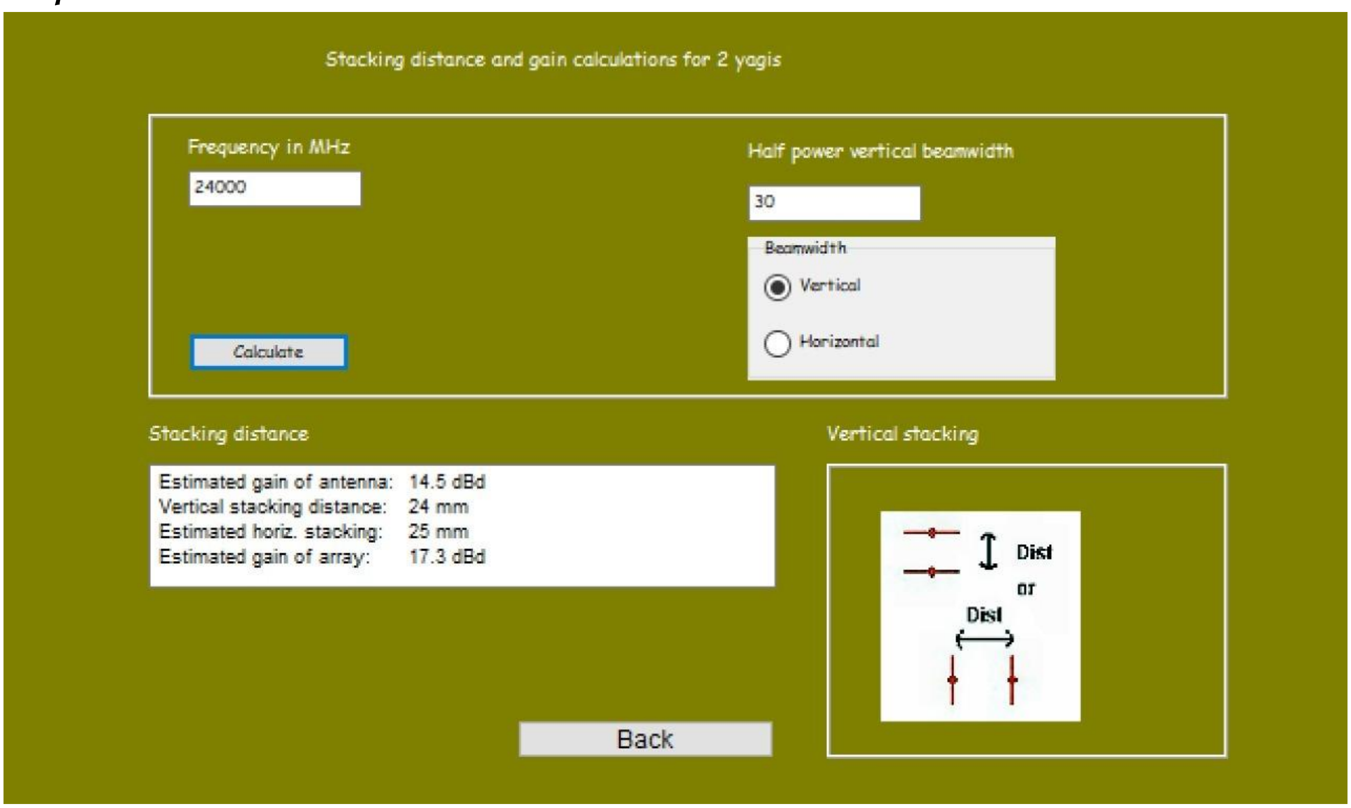
Step2:



Step3:


Gain calculations for long yagi
Enter frequency in MHz
2400
Boom length mm
1000
Calculate using
VK3AUU
WA2PHW
DJ9BV
Gain is 16.2 dBd (referred to dipole)
Approximate 3 dB beamwidth is 24.6 degrees
(Assuming E-plane and H-plane are the same)

Step4:


Stacking distance and gain calculations for 2 yagis
Frequency in MHz
24000
Half power vertical beamwidth
30
Beamwidth
Vertical
Horizontal
Calculate
Stacking distance
Estimated gain of antenna: 14.5 dBd
Vertical stacking distance: 24 mm
Estimated horiz. stacking: 25 mm
Estimated gain of array: 17.3 dBd
Vertical stacking
Dist
or
Dist
Back

APPLICATION ORIENTED LEARNING:

The following are the applications of Yagi-Uda antennas −

- Mostly used for TV reception.
- Used where a single-frequency application is needed.

CONCLUSION:

In the future, use of these antennas as elements of a phased array system may be made and the array performance as well as each individual element's behaviour may be characterized. Investigation on the location of the E and H-plane phase center over the entire antenna surface as opposed to only along its axis may also be conducted. Suitable techniques to reduce the crosspolarization levels of these antennas may also be suggested.

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