Antennas

Chapter 26

Your ‘connection’ to the ‘ether’...

Antennas convert electrical energy into radio waves that can be **radiated** long distances. Radiated means ‘in all directions’.

Pass a current along a wire and you will generate a magnetic and an electrostatic field. If you vary the current at a frequency, say 7 MHz [42.85 metres], the field will change over the length of the wire and proceed along that wire away from the source...

... and out into the “ether”.

Polarisation

Electromagnetic waves consist of a **magnetic field** and an **electric field** that are both at right angles to each other, and at right angles to the direction of propagation of the wave. The **polarisation** of radio waves depends on the **orientation of the electric field**—if the **electric field is horizontal**, the wave is said to be **horizontally polarised** and if it is **vertical**, the wave is **vertically polarised**.

Antennas do not respond well to radio signals with the "wrong" polarisation. {at VHF/UHF > 26 dB }

Also **balanced** antennas, distort their polar diagram when supplied from an **unbalanced** feedline.

The “isotropic” antenna.

Not just ‘theoretical’.
But radiates in all directions in a ‘uniform’ manner.

2.1 The isotrope

An isotrope or point source radiator radiates energy equally in all directions. Hence, its radiation is isotropic and the radiation pattern in any plane is a circle.

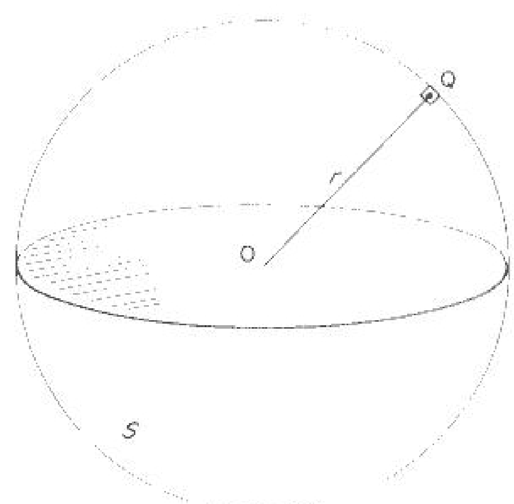


Fig. 2

What can you ‘use’ an Isotropic Antenna for?

Radar equation

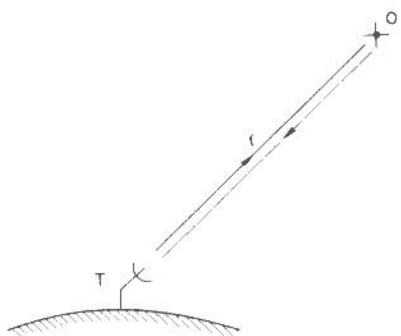


Fig. 3

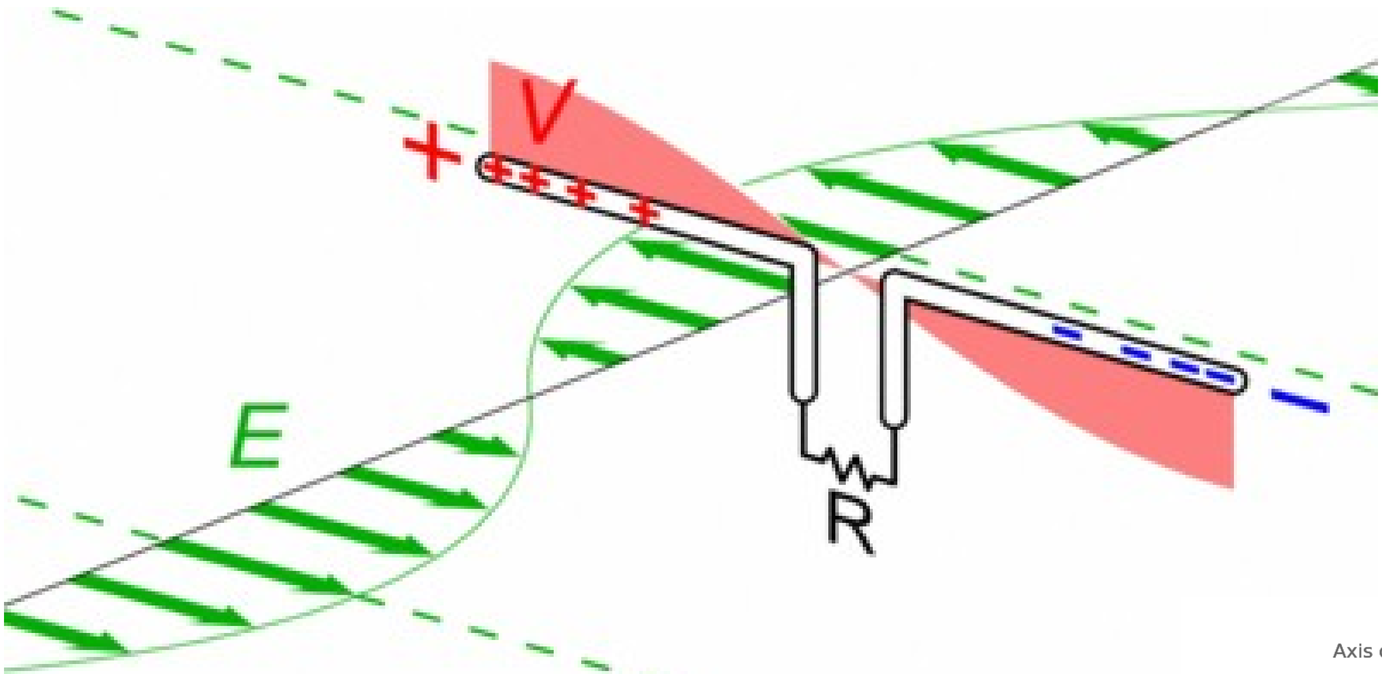
Suppose a radar transmitter at T in Fig. 3 has an antenna gain G_T and is transmitting a power P_T. The power density P_d at an object located at 0 distant r is

$$P_d = \frac{P_T \, . \, G_T}{4\pi r^2} \text{ watts/m}^2$$

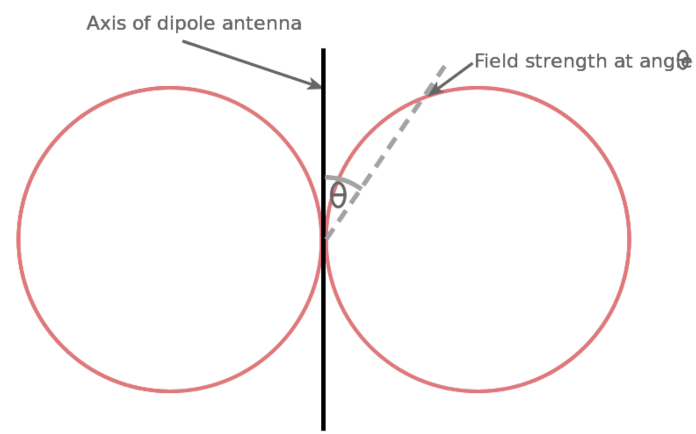
An aeroplane at a distance of say 100 km, appears to be a ‘point’ and reflects radio energy from the transmitter...

The ‘Dipole’ Antenna

It does **NOT** radiate in all directions in a ‘uniform’ manner.



Polar Diagram -->



The ‘Dipole’ Antenna 2

It does **NOT** radiate in all directions in a ‘uniform’ manner.

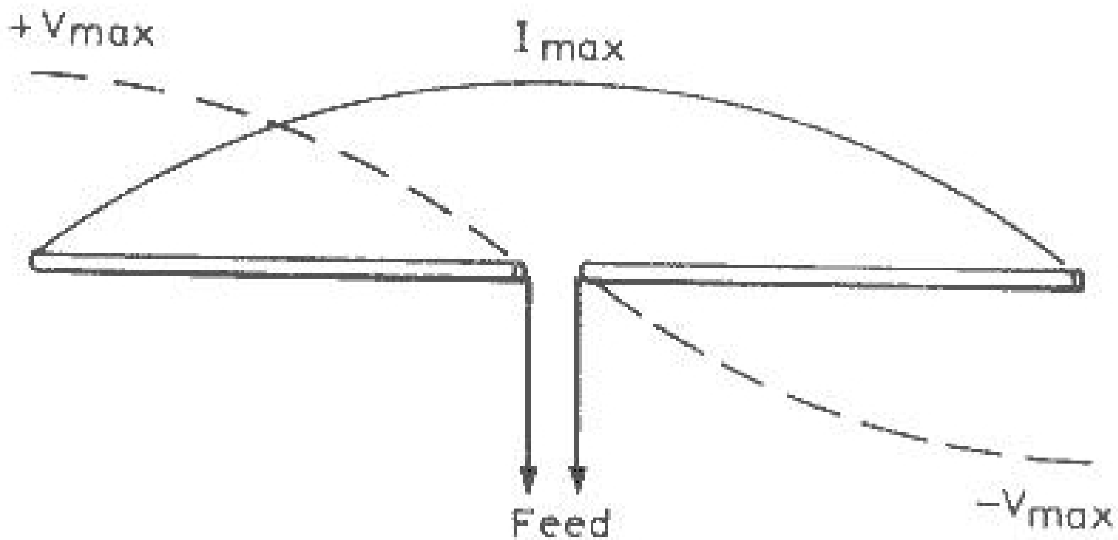
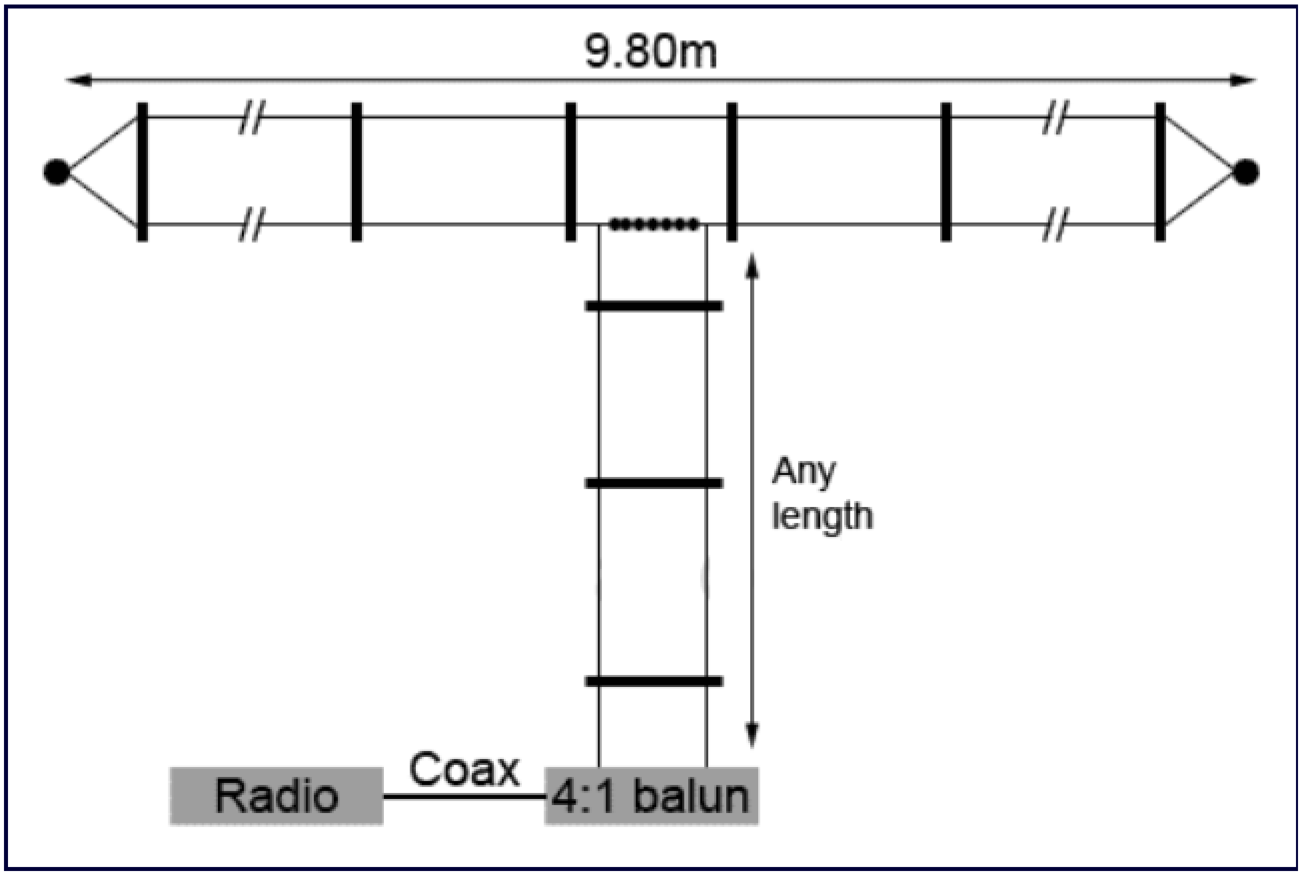


Fig. 1.11. Current and voltage distribution on a half-wave dipole

The ‘feed’ impedance is approximately 72 Ohms [Resistive]
It can be changed ...

The ‘Folded Dipole’ Antenna 3

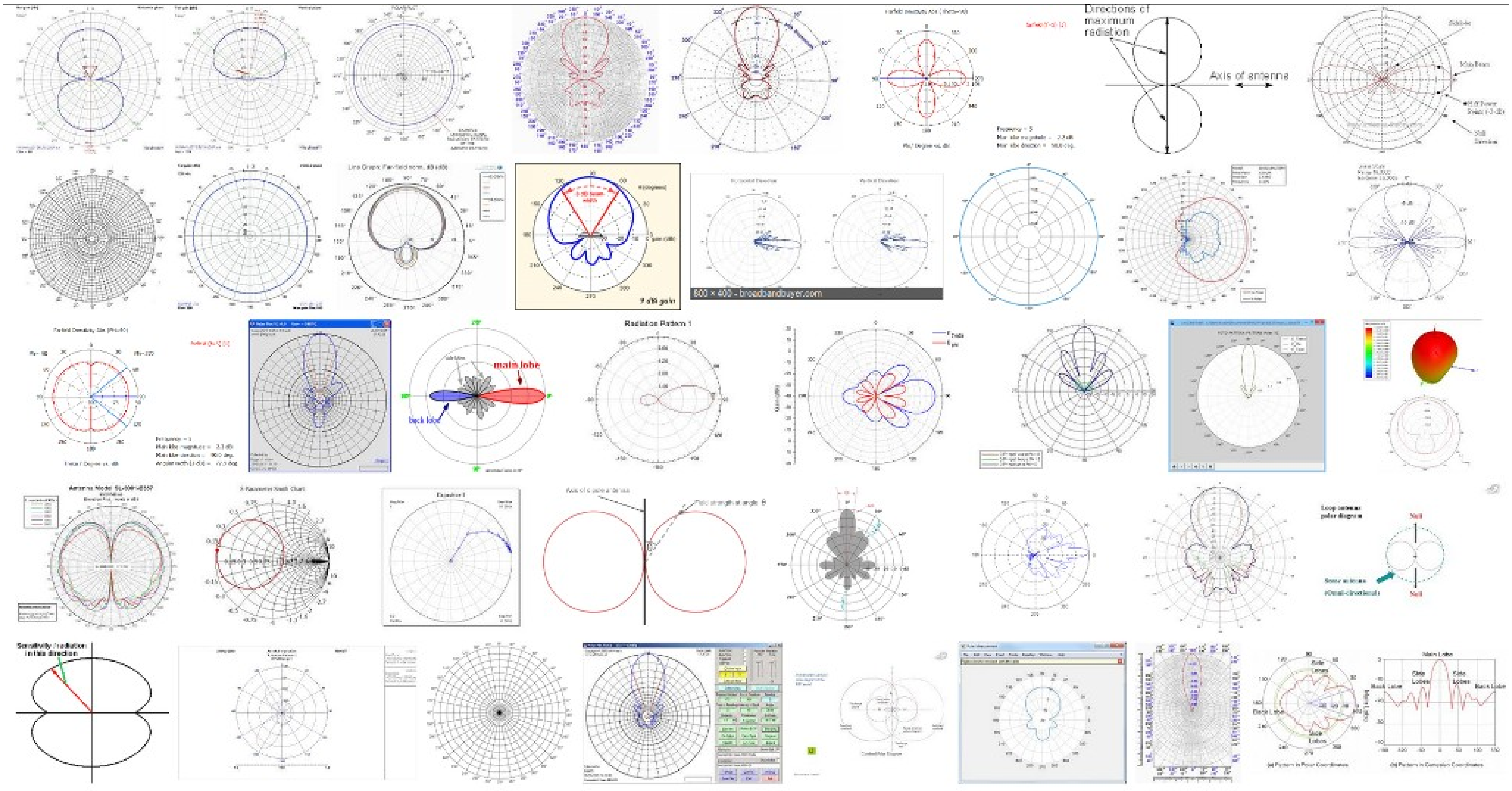
It does **NOT** radiate in all directions in a ‘uniform’ manner.



The ‘feed’ impedance is approximately 300 Ohms [Resistive]
This is from ZS6HVB’s web site. So ‘relevant’ to local hams.

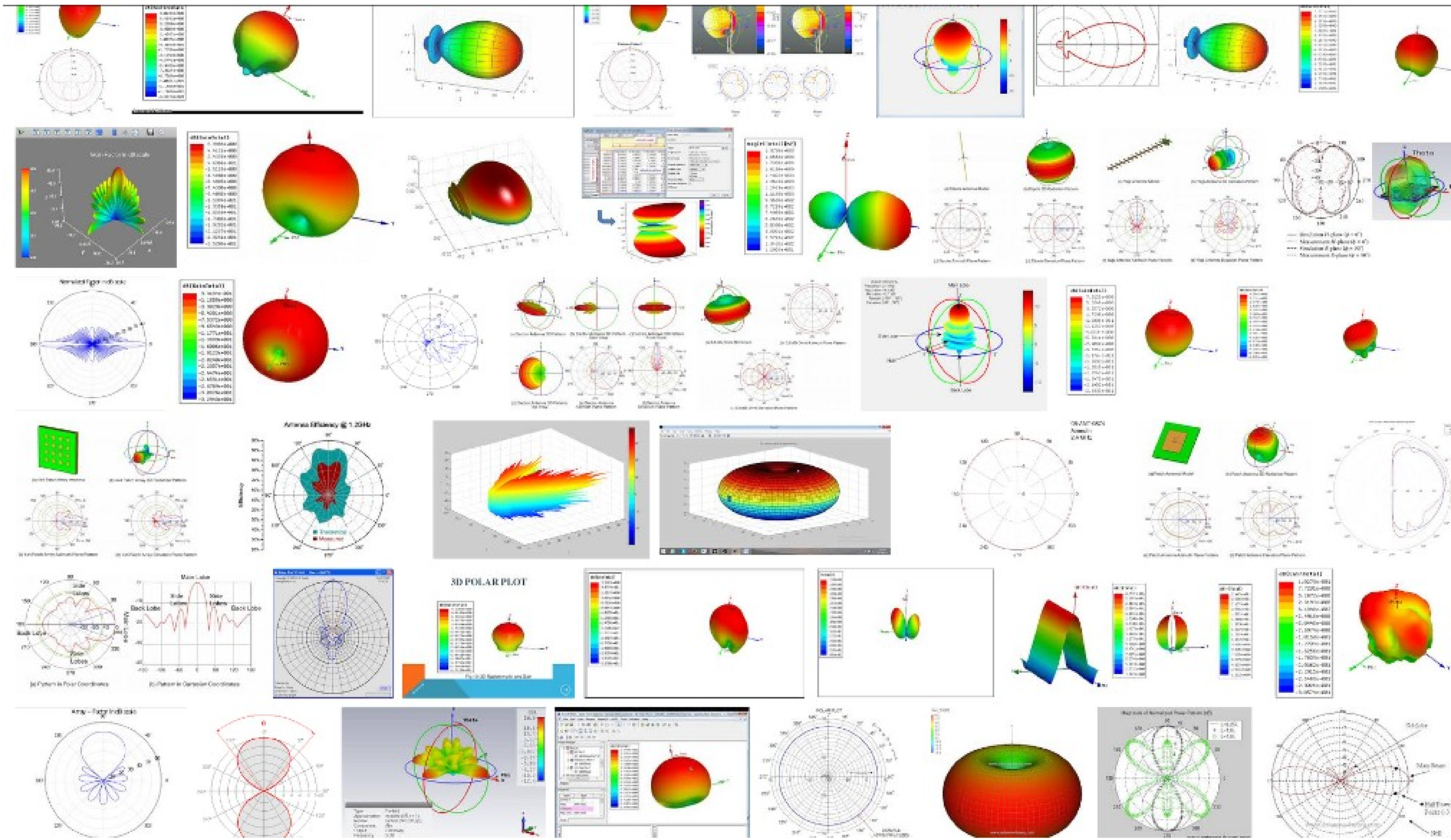
Antenna Polar Diagrams

It does **NOT** radiate in all directions in a ‘uniform’ manner.



Antenna Polar Diagrams

It does **NOT** radiate in all directions in a ‘uniform’ manner.



Capture Area and Radiation Resistance

Every antenna has a **capture area**, which represents the cross-section from which the antenna can extract energy from an incoming radio wave.

The half-wave dipole consists of a centre-fed ½λ element. Its **radiation resistance** is approximately 72 Ω. In free space, a dipole has a doughnut-shaped radiation pattern.
A horizontal dipole over ground has a bi-directional pattern similar to a figure “8”.

Dipoles can be deformed to fit into available space, or erected from a single support as an Inverted V.

The ‘Quarter-Wave’ Vertical

The ¼ λ vertical consists of a **vertical ¼ λ radiator** that is fed either against ground or against a “ground-plane”. It has an **omni-directional** pattern, radiating equally in all azimuth directions.

[It is an unbalanced antenna]

It is possible to use a vertical antenna with an ATU or phasing circuit.
That basically re-tunes the antenna to the desired frequency.

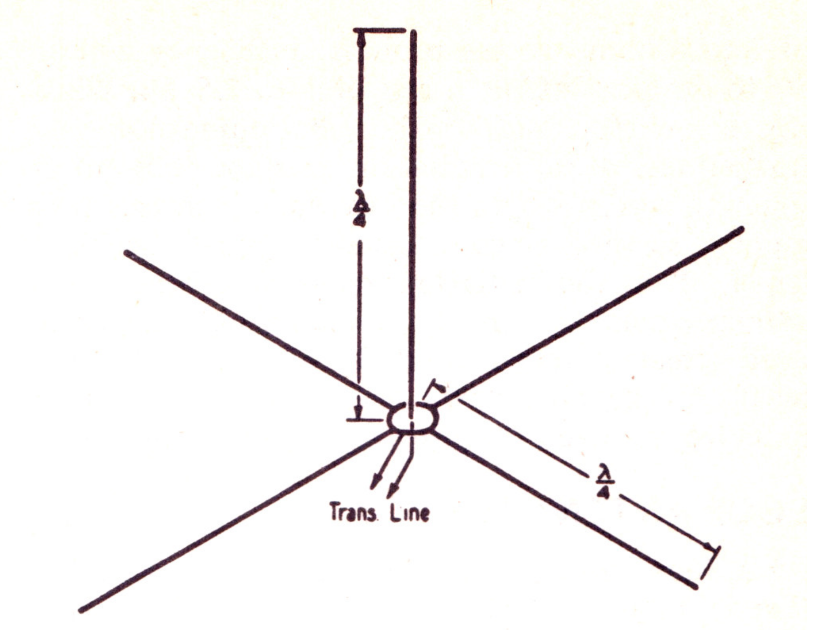


Fig. 2-81 — The ground-plane antenna. Power is applied between the base of the antenna and the center of the ground plane, as indicated in the drawing.

Wire Antennas

Resonances of a half-wave dipole antenna at odd multiples of its lowest resonant frequency are sometimes exploited. For instance, amateur radio antennas designed as half-wave dipoles at 7 MHz can also be used as 3/2-wave dipoles at 21 MHz

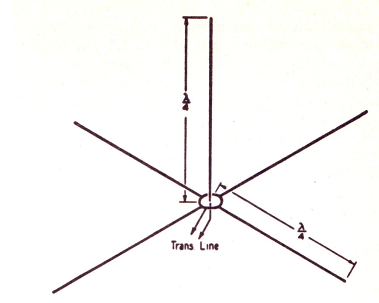


Fig. 2-81 — The ground-plane antenna. Power is applied between the base of the antenna and the center of the ground plane, as indicated in the drawing.

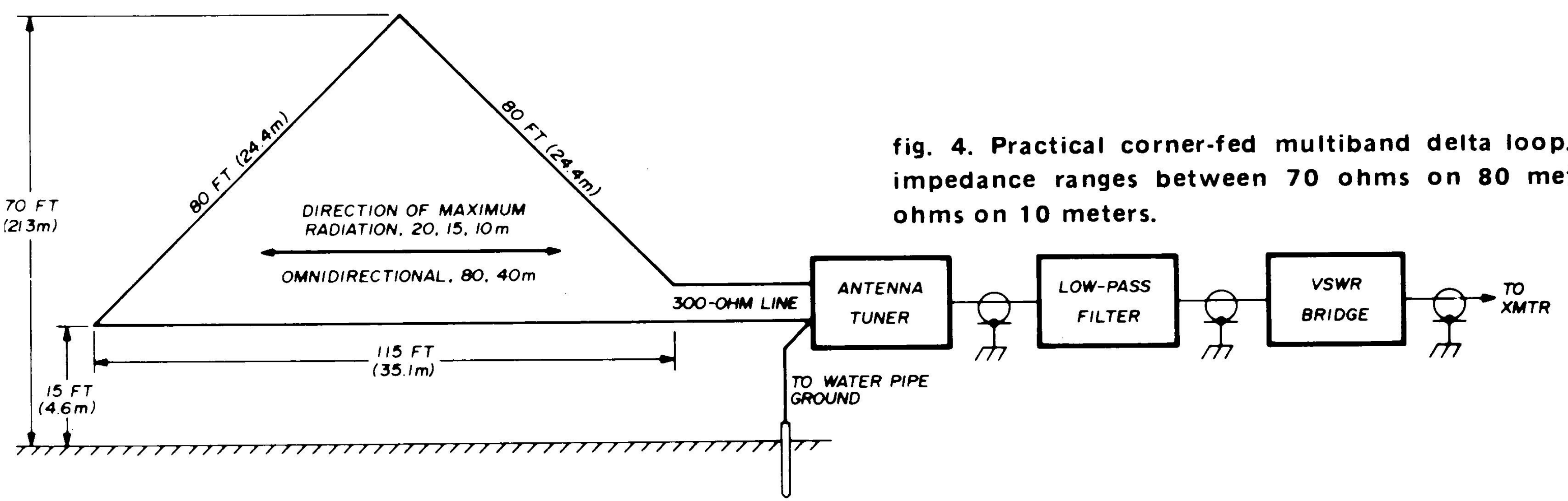
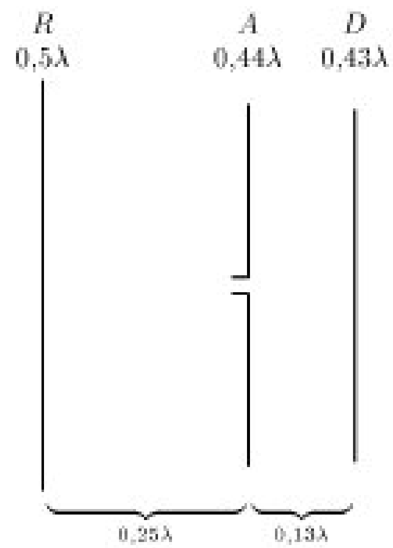


fig. 4. Practical corner-fed multiband delta loop. Feedpoint impedance ranges between 70 ohms on 80 meters to 300 ohms on 10 meters.

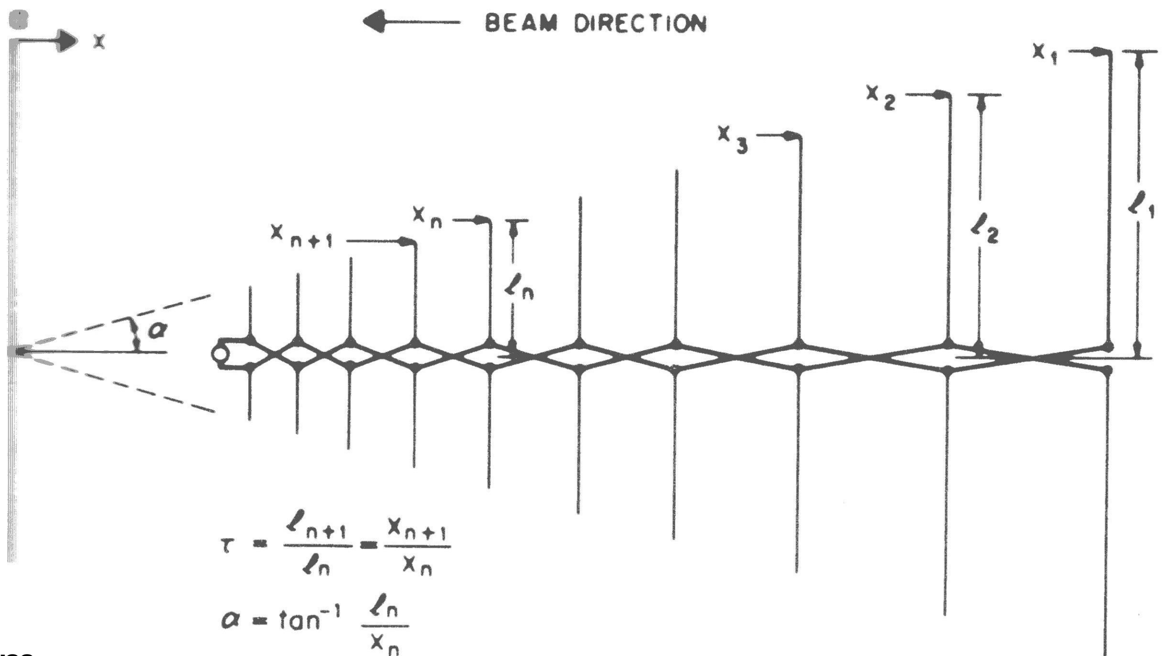
Directional Antennas

A **unidirectional** pattern can be achieved using a **multi-element** antenna, either a '**phased array'** where each element is individually fed from a phasing network, or a **'parasitic array'**, where the transmitter feeds only one element and the others are excited by inductive coupling from other elements.

The most common parasitic array is the **Yagi**, which consists of two or more elements—the **driven element**, a **reflector**, and one or more **directors**. All elements are approximately ½ λ long.

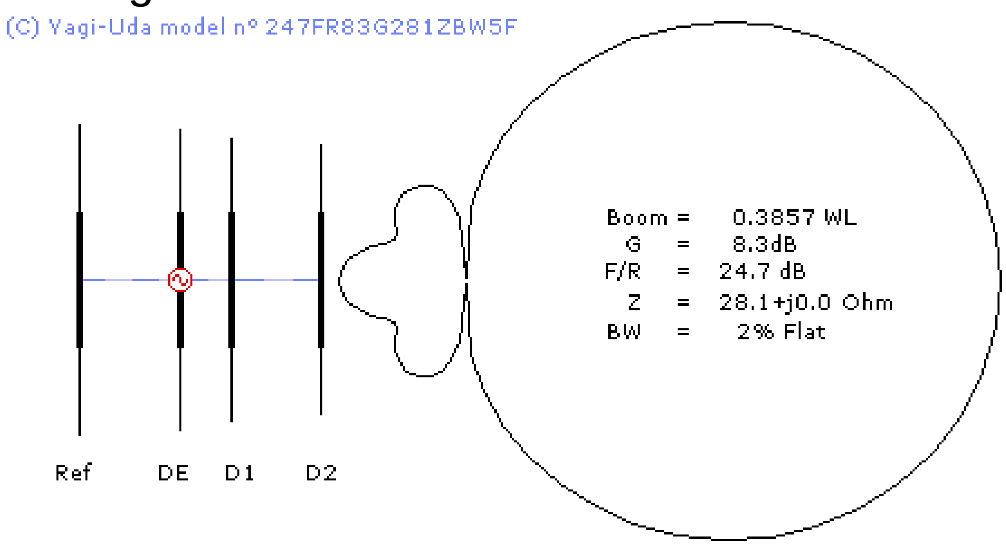


Directional Antennas 2

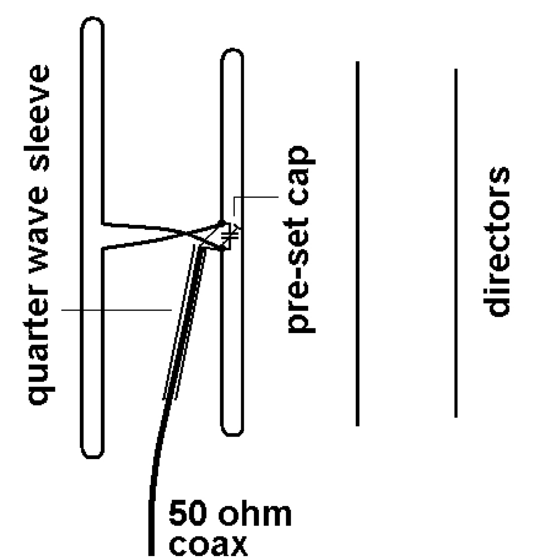


Log-Periodic beam

Yagi-Uda beam



ZL Special beam



The "DISH"

A dish or reflector antenna uses a dish-shaped reflector to concentrate the energy from the feed point in a specific direction. Dishes are mostly useful on **UHF** and **above**, as they must be many wavelengths in diameter to provide useful gain. The **feedpoint** can consist of a relatively simple antenna such as a **dipole** or **horn**.

Antenna Gain ?

=

Directivity

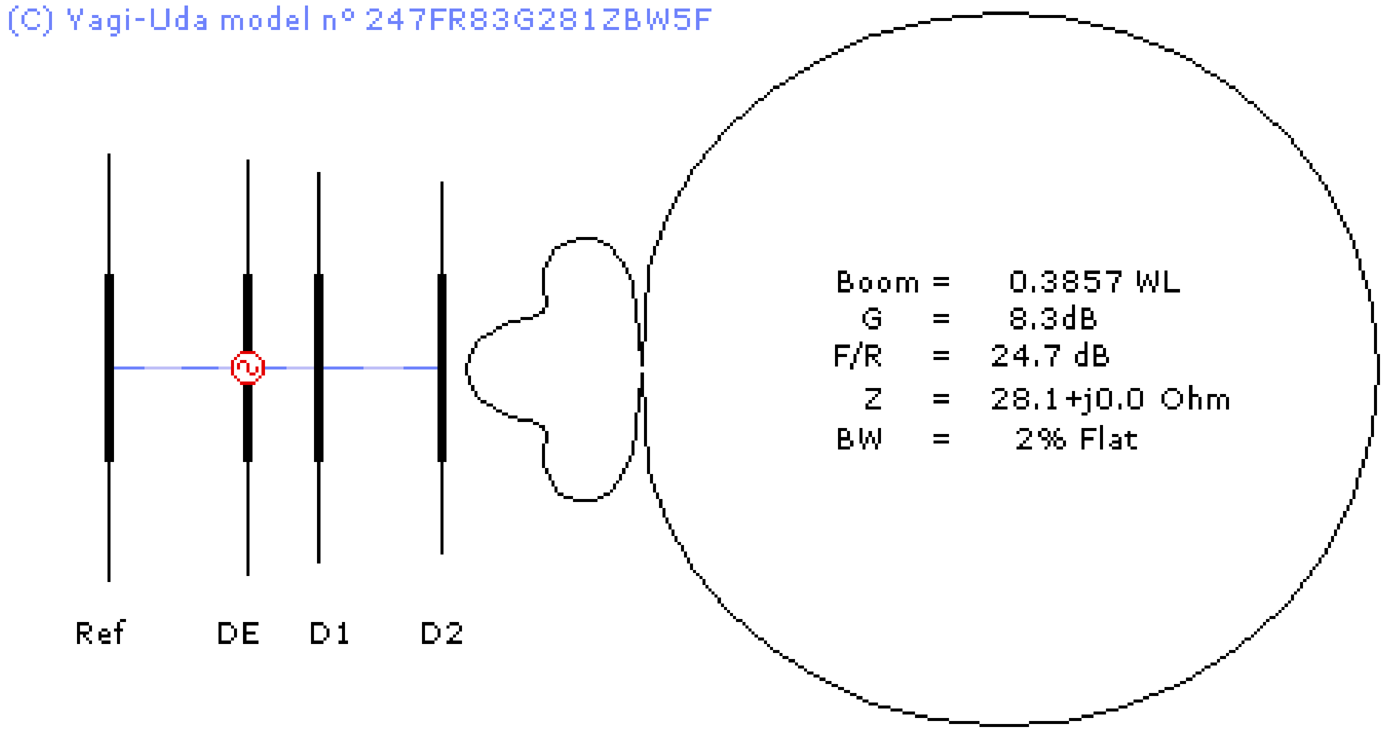
The **gain** of antenna expresses how much power is radiated in the most favoured direction, compared with some **reference antenna**. Gain can be specified in **dBd** (dB compared to a dipole) or in **dBi** (dB compared to an isotropic radiator). The efficiency of antenna is the amount of power radiated as a percentage of the total power applied to the antenna.

The **Effective Isotropic Radiated Power (EIRP**) is the power fed to the antenna multiplied by the gain of the antenna with respect to an isotropic radiator.

Identical antennas can be **stacked** and fed together to provide improved performance.

Antenna Parameters

Other important parameters of antennas (apart from gain) include **beamwidth**, **sidelobe suppression** and **front-to-back ratio** (**F/B**).



Feedlines [cables]

Feedlines come in two varieties:
Balanced and unbalanced.

Balanced feeders offer low loss and simplicity under some conditions, but are prone to interaction with nearby structures. [This depends on how well-balanced they are...]

Their impedance can be shaped by changing the wire spacing.

Coaxial cables have a fixed **characteristic impedance**, and are more or less impervious to outside influences if fed properly. They can become very lossy over long distances or at high frequencies.

Feeding the Antenna

Energy travels slower in feedlines than in **‘free space’**.

As a result, the wavelength is less in a feedline than one would expect.

The ratio between the actual wavelength and the free-space wavelength is known as the **velocity factor**.

For coaxial cables, this factor is around 0.66 Average.

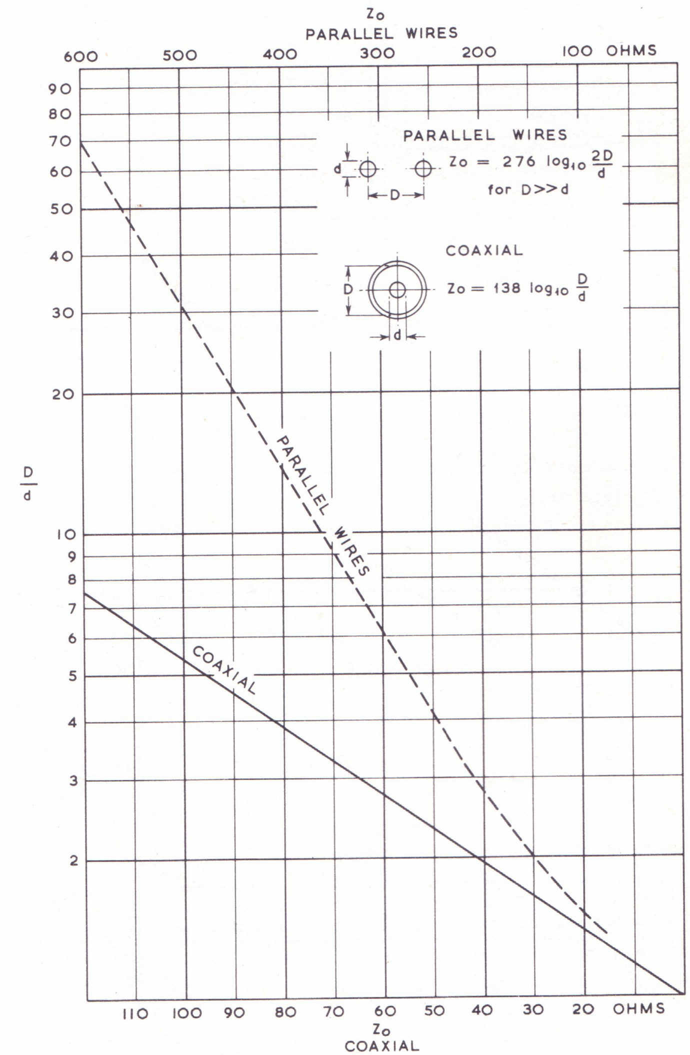


Fig 7.22. Chart showing feeder line impedances for coaxial or open wire lines

Feeding the Antenna 2

Table 7.1

Characteristics of typical British radio frequency feeder cables

Type of cable	Nominal Impedance Z_o (Ω)	Centre Conductor	Dimensions (in) over outer sheath	Dimensions (in) over twincores	Velocity factor	Approximate attenuation (dB per 100ft) 70MHz	145MHz	430MHz	1250MHz	Remarks
Standard tv feeder ..	75	7/.0076	0·202	—	0·67	3·5	5·1	9·2	17	—
Low-loss tv feeder (semi-air spaced) ..	75	0·048	0·290	—	0·86	2·0	3·0	5·4	10	Semi-air spaced or cellular
Flat twin	150	7/.012	—	0·18 0·09	approx. 0·71	2·1	3·1	5·7*	11*	*Theoretical figures, likely to be considerably worsened by radiation
Flat twin	300	7/.012	—	0·405 0·09	0·85	1·2	1·8	3·4*	6·6*	
Tubular twin	300	7/.012	—	0·446	0·85	1·2	1·8	3·4*	6·6*	

RF Cables British UR series

UR No	Nominal Impedance Z_o (Ω)	Overall diameter (inches)	Inner conductor (inches)	Capacitance (pF/ft)	Maximum Operating voltage rms	Approximate Attenuation (dB per 100 ft) 10MHz	100MHz	300MHz	1000MHz	Approx RG. equivalent
43	52	0·195	0·032	29	2750	1·3	4·3	8·7	18·1	58/U
57	75	0·405	0·044	20·6	5000	0·6	1·9	3·5	7·1	11A/U
63*	75	0·853	0·175	14	4400	0·15	0·5	0·9	1·7	
67	50	0·405	7/0·029	30	4800	0·6	2·0	3·7	7·5	213/U
74	51	0·870	0·188	30·7	15000	0·3	1·0	1·9	4·2	218/U
76	51	0·195	19/0·0066	29	1800	1·6	5·3	9·6	22·0	58C/U
77	75	0·870	0·104	20·5	12500	0·3	1·0	1·9	4·2	164/U
79*	50	0·855	0·265	21	6000	0·16	0·5	0·9	1·8	
83*	50	0·555	0·168	21	2600	0·25	0·8	1·5	2·8	
85*	75	0·555	0·109	14	2600	0·2	0·7	1·3	2·5	
90	75	0·242	0·022	0	2500	1·1	3·5	6·3	12·3	59B/U

All the above cables have solid dielectric with a velocity factor of 0·66 with the exception of those marked with an asterisk which are helical membrane and have a velocity factor of 0·96.

This table is compiled from information kindly supplied by Aerialite Ltd, and BICC Ltd and includes data extracted from Defence Specification, DEF-14-A (HMSO)

Standing Wave Ratio - swr

Standing-wave ratio (SWR) indicates how well an antenna is matched to the feedline, and is expressed as a ratio of 1:1 or greater.

An SWR of 1.5:1 at the transmitter is considered good enough, and up to 2:1 can be tolerated.

Reflection coefficient = Vreflected / Vforward

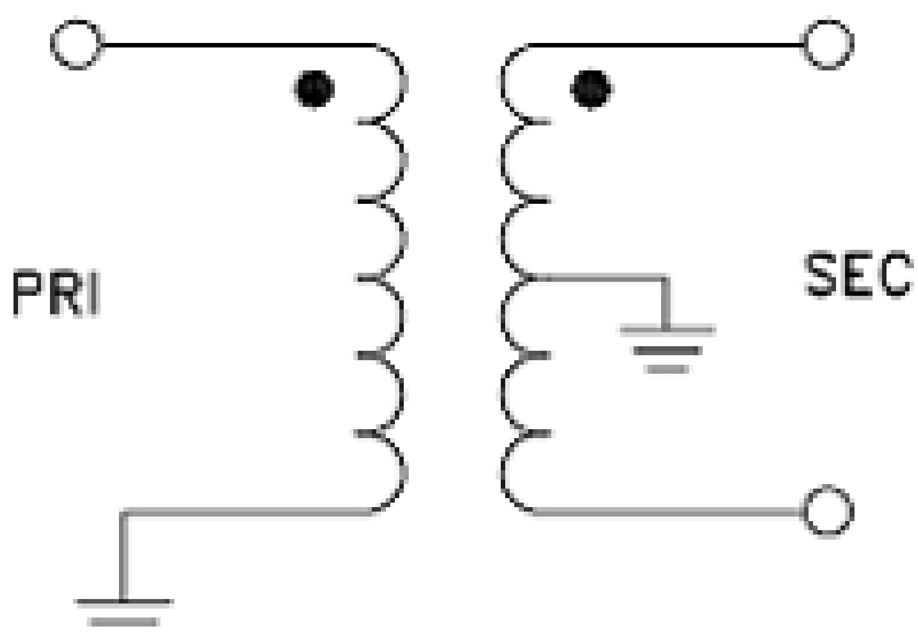
Non-Amateurs [Professionals] use “Return Loss Ratio” Which immediately gives the ratio of power reflected from a mis-match...

$$RL(\mathrm{dB}) = 10 \log_{10} \frac{P_\mathrm{i}}{P_\mathrm{r}}$$

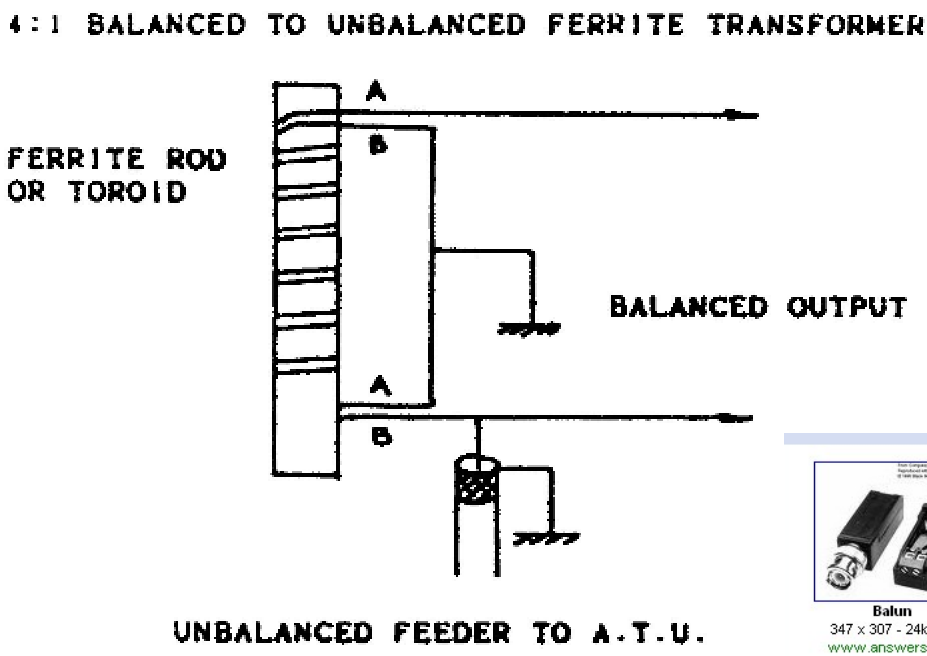
Baluns

A **balun** (balanced to unbalanced transformer) should be used to match balanced loads to unbalanced coaxial cables to **prevent interference (radiation) from currents flowing in the braid**.

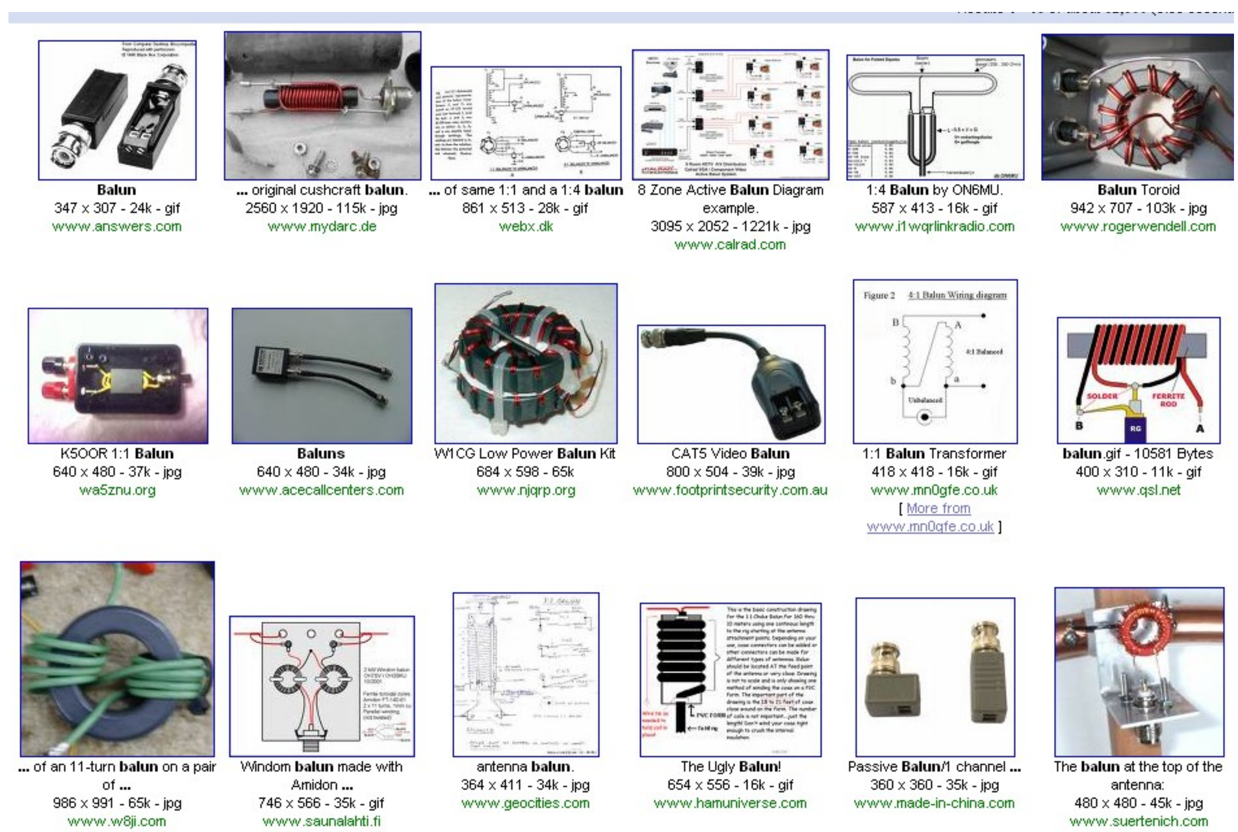
[A balun is also called; a "Braid Breaker".]



Baluns...



4:1 BALANCED TO UNBALANCED FERRITE TRANSFORMER
FERRITE ROD
OR TOROID
A
B
BALANCED OUTPUT
A
B
UNBALANCED FEEDER TO A.T.U.



Balun
347 x 307 - 24k - gif
www.answers.com
... original cushcraft balun.
2560 x 1920 - 115k - jpg
www.mydarc.de
... of same 1:1 and a 1:4 balun
861 x 513 - 28k - gif
webx.dk
8 Zone Active Balun Diagram example.
3095 x 2052 - 1221k - jpg
www.calrad.com
1:4 Balun by ON6MU.
587 x 413 - 16k - gif
www.i1wqrlinkradio.com
Balun Toroid
942 x 707 - 103k - jpg
www.rogerwendell.com
K5OOR 1:1 Balun
640 x 480 - 37k - jpg
wa5znu.org
Baluns
640 x 480 - 34k - jpg
www.acecallcenters.com
W1CG Low Power Balun Kit
684 x 598 - 65k
www.njqrp.org
CAT5 Video Balun
800 x 504 - 39k - jpg
www.footprintsecurity.com.au
1:1 Balun Transformer
418 x 418 - 16k - gif
www.mn0gfe.co.uk
[More from www.mn0gfe.co.uk]
balun.gif - 10581 Bytes
400 x 310 - 11k - gif
www.qsl.net
... of an 11-turn balun on a pair of ...
986 x 991 - 65k - jpg
www.w8ji.com
Windom balun made with Amidon ...
746 x 566 - 35k - gif
www.saunalahti.fi
antenna balun.
364 x 411 - 34k - jpg
www.geocities.com
The Ugly Balun!
654 x 556 - 16k - gif
www.hamuniverse.com
Passive Balun/1 channel ...
360 x 360 - 35k - jpg
www.made-in-china.com
The balun at the top of the antenna.
480 x 480 - 45k - jpg
www.suertenich.com

Impedance Matching

An antenna may be **impedance-matched** on multiple bands by using an **antenna tuner**, by feeding multiple elements in parallel, by using traps or by taking advantage of naturally occurring **harmonic resonances**.

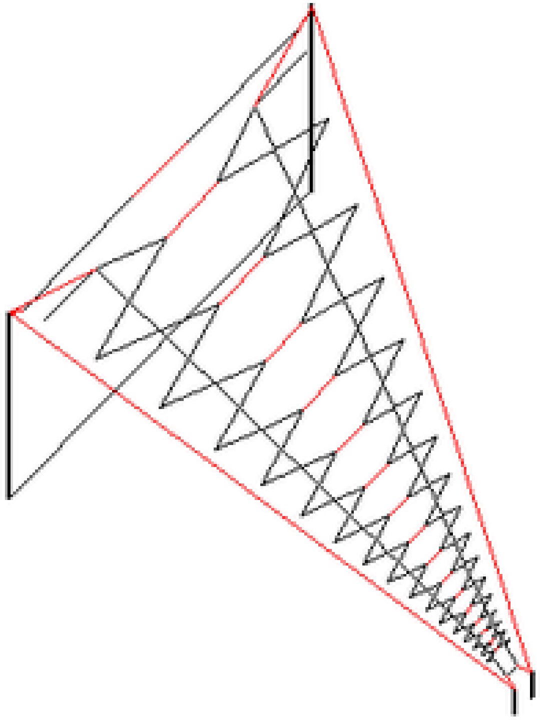
OR

You can use a 4:1 Balun or a 9:1 Balun...

Broadband Antennas

The Log-Periodic Array (LPA) provides wide frequency coverage with modest gain.

Log-Periodic Antenna



Discone Antenna

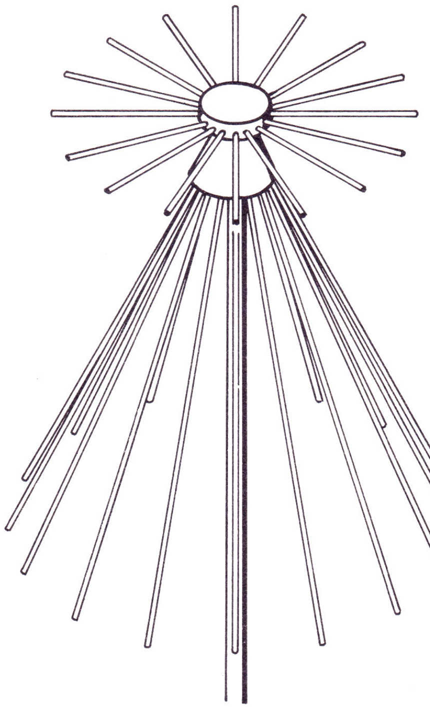


Fig 7.59. General arrangement of skeleton form of Discone aerial

Antenna Experimentation

HF antennas provide an excellent starting point for antenna experimentation. All you need are a few egg insulators, some coax cable and some bare copper wire.

- Theory of reciprocity
- Field strength measurement
- Antenna ‘scaling’ works. Build at 70 cm, use at H.F.
- GAIN is equivalent to "Directivity"
- Length to thickness ratio for bandwidth.
- Transmission line (theory). Infinite line.
- Stub matching
- Loop antennas for High Q - narrow bandwidth.

Antenna Notes

Wavelength [lambda] = $300 * 10^6$ / F [in MHz]

finding the right tapping points along the stub for the feeder/balun connection. The configurations for 2-, 3- and 4-element collinears are shown in Fig. 2.12.

A two-element collinear

This is sometimes referred to as the 'plumbers delight' as the elements and stub are made from copper water pipe joined with appropriate fittings. Note that a blow lamp is needed to soft solder the fittings.

The antenna is self supporting and can be mounted on the top of a metal mast as shown by means of a T junction let into the lower leg of the stub and coupled to the mast by a length of PVC waste pipe. Suitable couplers can be obtained for this from builder's merchants. All the dimensions are given in Fig. 2.14(a) and details for the balun feed will be found in Fig. 2.14(b). Adjust the tapping points (X) for maximum radiation with the aid of a field strength meter, series power meter, neon or fluorescent tube at voltage points etc., and also for low VSWR which should not be greater than about 1 to 1.2. Adjustment can be made on a received signal, i.e. adjust for maximum signal meter reading.

The balun feed loop is effectively a half-wavelength long but because of the velocity factor of the coaxial cable (same as used for the feed cable itself) it will be physically shorter, average 712 mm (28 in). The following simple formula will give the exact length for the type of coaxial cable used (e.g. UR43, UR67 etc.):

$$\text{length (m)} = \frac{150 \times \text{velocity factor of cable}}{145\ \text{MHz}}$$

The tapping points along the stub will be around 150 mm (6 in) from the closed end.

A Slim Jim collinear

This has been tested as a scale model at 650 MHz and as a full size version at both 145 and 430 MHz and is an extension of the Slim Jim described earlier. With any single-element close spaced collinear

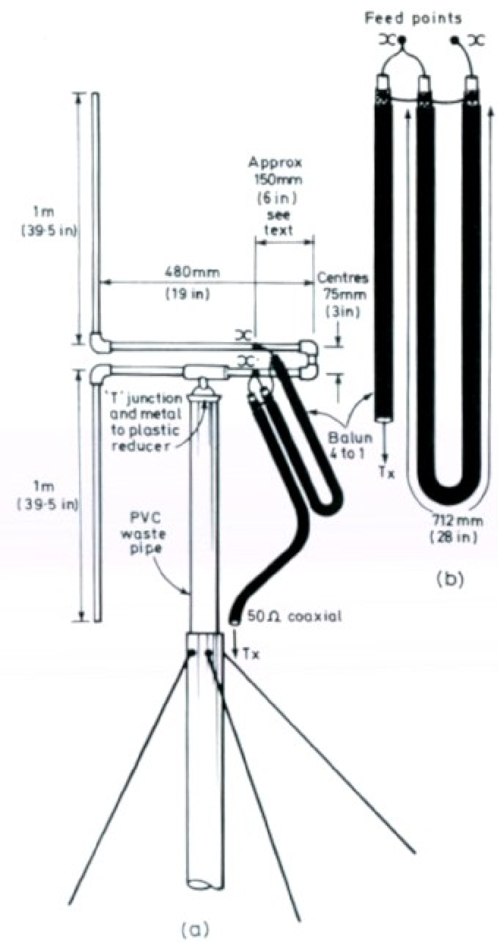


Fig. 2.14. (a) Construction of a two-element collinear from copper water pipe and fittings. (b) Details for the balun (see text)