Latest version of this document can be found at http://flakey.info/antenna/waveguide/
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Overview

We have been experimenting with waveguide antenna, made from old food cans, to mass

One of the antennas made from a J&B whiskey tin.

Note - This antenna is for use with 802.11b wireless computer networks or 2.4GHz video

This was evolved primarily since the Pringle's can antenna. The Pringle's can, being cardboard, does not last long in a storm, and it is very hard to affix connectors securely. The dipole-less "yagi" bit inside is fiddly to make, and initial tests show the waveguide cans to work better.

From studies of waveguide theory, which gets complicated, it seems that a waveguide antenna or "can-tenna" should have parallel sides, be a good conductor, preferably shiny, and the end needs to be be perpendicular to the sides. For 2.4 GHz the calculations indicate that the can should have a diameter between 70 mm (millimetres) and 100 mm. These are not a "brickwall" limits, but rather roll-off points. i.e. performance will diminish increasingly beyond these sizes.

From practical use we have found that strength is a good virtue, and a fitting plastic lid is almost a must for waterproofing. See appendix for a list of cans found suitable so far.

The ARRL (Amateur Radio Relay League) say that the required waveguide length is at least two guide wavelengths - The guide wavelength is the value of Lg (in the tables of values below) and is dependent upon the diameter of the can. The smaller the diameter, the longer the guide wavelength. This suggests the larger acceptable diameters should be used so the can may be shorter. Also the larger the area of the mouth of the can, the more energy can be tranferred, so the greater the received and transmitted signal.

Construction

First we selected a can with a diameter of 96 mm. We calculated from this the value for 1/4Lg (a quarter of the standing wavelength inside the can), measured this far up from the bottom of the can and drilled a small pilot hole, then drilled the hole out large enough for a chassis mount N-type connector. It is not easy to find 16 mm drill bits in the UK, so we bought a 20 mm cone cutter. To the pin of the chassis mount N-type connector we soldered about 50 mm of 1.5 mm diameter stiff copper wire. This wire was then carefully cut to the value

calculated
for 1/4Lo. The edges of the N-type connector and the can around the hole were then abraded heavily with glass paper. The N-type connector assembly was then soldered in place to the can, on all four sides. It is important to get a good electrical connection between the N-type connector and the can. Also we have now sourced round N-type connectors which screw into the can (from
rswww.com
stock no. 112-0773) , and just requires a 16 mm hole drilling.

Inside of the can, showing the driven element. Photo not taken whilst in use.

The cone cutter will cut a perfect hole if the 16 mm washer from the connector is placed over the tip before cutting. With the tools to hand, the whole process took ten minutes.

After a couple of years of experience and learning using these cantennas, it appears that it makes sense to drill a small hole in the can just behind the N-type connector. Thus any rain or condensation which finds its way into the can has an easy route out. The hole should not affect the performance of the antenna.

Detail, showing N-type connector affixed to the can.

Mounting

This antenna has a beamwidth of around 30 degrees and needs aiming. Also the polarisation is important, that is whether the driven element inside is pointing skywards (vertical) or sideways (horizontal) - this needs to match the antenna it is communicating with. We have been mounting them around a standard 25 mm television pole with a U-bolt attached to an adjustable mounting from a television antenna shop - this allows adjustment in the horizontal and vertical plane. This has then had a short piece of stainless steel tubing clamped in, attached to the can with glue and gaffer tape, or cable ties. None of these are a very good solution. This is one point needing more thought...

Cost

£5.50 for the N-type connector, and the can of your choice, plus the little bit of wire, and a tiny bit of solder. When we spent £20 on our can we got a free bottle of whiskey. ;-)

Warning

Apart from the fact it works really well, no-one has yet popped on their lab-coat and done any high-brow tests on this "homebrew twig", and of course manufacturers recommend you don't do anything which they don't recommend. Or attach non-proprietary stuff to their stuff. Of course.

Tests on first construction

Our first waveguide antenna had a diameter of 96 mm, with a length greater than 3/4Lg and was made from a can which came with a bottle of gin :-)

The antenna was fitted with a standard television 75 Ohm connector (not a proper N connector). The pigtail used was made by removing the lead from a Buffalo Extended Range Antenna and attaching a standard television 75 Ohm connector. We are aware that the combination of 50 Ohm coaxial cable and 75 Ohm connectors is not a good impedance match and would result in loss, but at the time of testing, in Portugal, that is all we had, and we were keen.

Comparison was made with respect to the internal antenna on a Buffalo PCMCIA 802.11b card. Using Wavemon (a wireless measurements tool) on a GNU/Linux laptop to measure received signal strength, noise and signal to noise ratio.

Results

Our first can, including cable loss we received around +4 to +5 dB (deciBels) improvement in received signal strength, and a +10 dB improvement in signal/noise ratio.

Looking at data tables we estimate the coaxial cable used to have a 1.5dB loss.

This antenna allowed us to maintain an 11 Mbps connection at 200 metres from the Buffalo Airstation Extended Range Antenna. We could not walk far enough with clear line of sight. We were impressed that this improvement was measured even using cheap television connectors from the supermarket (at the wrong impedance).

First mountain test

Finally we managed to get hold of some 50 Ohm N-type connectors. Unfortunately no-one seemed to stock the mating pair so we had no option than to reduce to BNC and back up again at the other end. This worried us not as we were eager.

The only cable we could get hold of was

RG58/U, fairly high loss

We attached a gin can waveguide antenna to the Buffalo airstation, via 10 metres of cable, and pointed the antenna out of the window towards the HILL

Iain went to the top of the HILL with his laptop, running Wavemon on GNU/Linux, and a dogfood can-tenna, via 2 metres of cable. The top of the hill has two large multi-sector mobile phone antennas, broadcasting around 800MHz, we believe. Iain was positioned roughly 50 metres below them (slowly frying his brain!).

We had a clearish (tree tops) line of sight down the valley which measured 2200 metres point to point on the military map.

Results

We achieved a 2Mbps connection, with around 7 to 8 dB to spare, although in the excitement the figures got a little lost. Well, completely lost. The important part for us at this point was that it worked.

Having looked at the specification sheet for the cable we were using, it seems not to rate as high as 2.4GHz in the losses, the highest rating is at 1000 MHz which is 0.79dB per metre. This means that by using far too much of the wrong cable we have cost ourselves 9 to 10 dB. This is good news for our next hilltop shot with short good cables, and suggests a clear 5000 metre shot.

The can shown above has given us 16 to 17dB improvement over the antenna on the Buffalo wireless card. This is successful. We are very happy with the results of this can.

We are now awaiting some spare time and enough clear space to do further range tests. We are expecting 10,000 metres on a can to can link.

Appendix
List of tins so far found to be suitable

- Slimfast Double Chocolate - England - with plastic lid
- The Simpsons Double choc cookies - England - with plastic lid
- Douwe Egberts ground coffee - England - with plastic lid
- Baby milk formula - England - with plastic lid
- Furness Ginger Biscuits - Cornwall and England
- Golden Jubilee Beer, Robert Cain Brewery - England
- J&B Rare whiskey tin - Portugal
- Larios Gin - Spain

- Stainless steel toilet brush holder from B&Q - very nice (thanks to Robert Currey)
- Any large dog food tin at a push, if you can't find anything better!

Some colourant additives in the plastic lids affect signal, so test with lid off and on, and if the signal is detrimented, use without.

References and links

- http://www.saunalahti.fi/elepal/antenna2.html - waveguide antenna theory

- http://www.qsl.net/n9zia/wireless/pics/tincanant.jpg - original inspiration
- A whole hand full of library books on waveguide theory, which I didn't note down before handing back...

Circular waveguide antenna calculator - JavaScript

See Fig1.1 for how to use values - most of them are unnescessary and slightly confusing.

- D is the interior diameter of the can
- Lo is wavelength in open air = 0.122 metres
- Lc is wavelength at lower dominant mode cut off frequency
- Lu is wavelength at higher dominant mode cut off frequency
- Lg is standing wavelength inside can

Lc = 1.706D

Lu = 1.306D

Lg = 1 / (sqr_rt{(1/Lo)2 - (1/Lc)2})

Ideally for the usual operating range of 802.11b:

- Lower cut-off frequency should be lower than 2400 MHz
- Upper cut-off should be higher than 2480 MHz

The form calculation below requires javascript. Jump straight to a table of values instead.

D in mm

Lower cutoff frequency in MHz

Upper cutoff frequency in MHz

Lg in mm

Lg / 4 in mm - needed to make can

3Lg / 4 in mm

Lo / 4 in mm - needed to make can

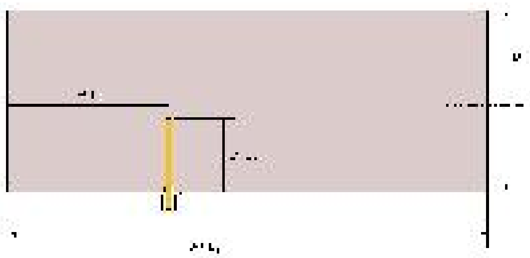

Fig 1.1 - Circular waveguide antenna showing design values, click to enlarge. **Table 1.1 - wavelengths and frequencies against diameter**

See Fig1.1 for how to use values

D in mm	D in inches	Lower cut off frequency in MHz	Upper cut off frequency in MHz	1/4 Lg	3/4 Lg	1/4 …
73	2.874	2407.23[illegible]	3144.52[illegible]	[illegible]		
74	2.913	2374.70[illegible]	3102.02[illegible]	[illegible]		

75	2.952	2343.043	3060.664	44
76	2.992	2312.214	3020.396	38
77	3.031	2282.185	2981.173	34
78	3.07	2252.922	2942.953	31
79	3.11	2224.408	2905.697	29
80	3.149	2196.603	2869.378	28
81	3.188	2169.485	2833.952	26
82	3.228	2143.027	2799.391	25
83	3.267	2117.208	2765.664	24
84	3.307	2092.003	2732.739	23
85	3.346	2067.391	2700.589	23
86	3.385	2043.352	2669.187	22
87	3.425	2019.865	2638.507	21
88	3.464	1996.912	2608.524	21
89	3.503	1974.475	2579.214	20

90	3.543	1952.533	2550.556	20
91	3.582	1931.082	2522.528	20
92	3.622	1910.092	2495.111	19
93	3.661	1889.551	2468.281	19
94	3.7	1869.449	2442.022	19
95	3.74	1849.771	2416.317	18
96	3.779	1830.502	2391.147	18
97	3.818	1811.631	2366.496	18
98	3.858	1793.145	2342.348	18
99	3.897	1775.033	2318.688	17

Author: spacepleb@psand.net