TechTalk#101

DATV – Looking at a "Slot" Antenna for 1.2 GHz

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I have been occasionally running into "slot antenna" discussions ever since I got interested in Digital-ATV. I decided to take a closer look at the slot antenna design, try to understand how it works, and see if the slot antenna might be might be the best approach for me on 1.2 GHz. This article is intended to explain concepts on how the slot antenna works and allow you to compare it to other antenna designs. This article is an overview and will not teach you the details that you need to actually build one. If you are interested in building one, there are plenty of design and construction articles available on the web.

Microwave Waveguides

The heart of the basic slot antenna is the use of microwave Waveguide for construction. In ham radio, I managed to avoid working with waveguides by working mostly with frequencies of 440 MHz and down…where coax cable had acceptable performance. So I need to start by explaining "what is a waveguide". A microwave waveguide is a very low loss transmission line for RF at microwave frequencies. A waveguide model called WR-90 creates about 0.1 dB of loss per meter as transmission line at a frequency of 10 GHz. Compare that loss with Beldon 9913 coax at about 0.62 dB/M loss at 10 GHz and 0.17 dB/M loss at 1.3 GHz…or LMR-400 coax at about 0.50 dB/M loss at 10GHz and 0.16 dB/M at 1.3 GHz.

In general, a waveguide consists of a rigid hollow metallic tube. Common waveguide shapes are rectangular, square, circular, and ridged. A very typical waveguide for the X-Band (frequency range of 8.2 to 12.4 GHz) is the USA standard rectangular waveguide, model WR-90, that has an inner width dimension of 0.9 inches (2.286 cm) and an inner depth of 0.4 inches (1.016 cm). Different models of waveguide operate in different frequency ranges. Most models of waveguides use different dimensions and operate above 5 GHz. A few models like WR-650 (6.50 in x 3.25 in) will work at 1.2 GHz

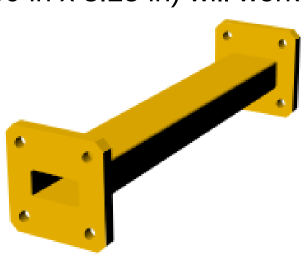

Figure 1 – A short Section of Rectangular Waveguide with Flanges for connecting to other sections
(Courtesy of Wikipedia on Waveguides)

Electromagnetic waveguides can be analyzed by solving Maxwell's equations with boundary conditions determined by the properties of the materials and their interfaces. This is pretty complex math (in my opinion) and I won't go in that direction. I will just leave this discussion on waveguides with the simple rule that if the waveguide is too narrow or if the RF wavelength is too long, the electromagnetic fields cannot propagate.

Basic Waveguide Slot Antenna

Slot antennas are a fairly common omnidirectional microwave antenna design. Waveguide slot antennas, usually consist of an array of slots for higher gain that can be used at frequencies from 1.2 to 24 GHz, A typical waveguide slot antenna is seen in **Fig 2**. Note that there are a total of 12 vertical slots machined into **Fig2**; six on the front side and six on the back side. BTW, you are looking through both sides of the waveguide through both sets of the slots.

Figure 2 – 10 GHz Slot Antenna made from WR-90 Waveguide with 12-slot array
(Courtesy of Paul Wade W1GHZ.org)

Paul Wade W1GHZ has a terrific online book called "W1GHZ Microwave Antenna Book" that describes a slot dipole as using a thin slot in an infinite ground plane. The slot dipole is a magnetic-field-dipole and it is the complement to a wire-dipole in free space. That is: the vertical slot is a magnetic-field dipole and has the radiation pattern as a one-half-wavelength horizontal wire-dipole (electric-field dipole) of the same dimensions. This horizontal polarization of the electric field is due to the fact that in electromagnetic radiation, the magnetic-field and the electric-field are oriented 90 degrees apart (perpendicular). The radiation pattern of a slot antenna is reasonably omnidirectional in the azimuth.

Number of Slots	Gain (max)	Gain (over free-space dipole)	Antenna Length
12 @ 10.3 GHz	13 dBi	~10.9 dBd	~148 mm
24 @ 10.3 GHz	16 dBi	~13.9 dBd	~260 mm
12 @ 1.3 GHz	13 dBi	~10.9 dBd	~1172 mm
24 @ 1.3 GHz	16 dBi	~13.9 dBd	~2060 mm

Table 1 – Comparing gain for different number of slots at 10.3 GHz and 1.3 GHz

The W1GHZ web site (listed at the end of this article) contains spreadsheets and formulas for calculating the dimensions and spacing for locating slots for various waveguide dimensions.

Connecting the COAX

So where and how do you hook up the coax cable to the slot antenna in **Fig 2**? Or if you use some additional waveguide sections as feed-line up the tower or up to the roof...how do you connect the coax to the waveguide?

The solution is to use an adapter to transition from the impedance of the waveguide to the 50 ohm impedance of coax. **Fig 3** shows a diagram of the construction of a Rectangular-Waveguide-to-Coax adapter.

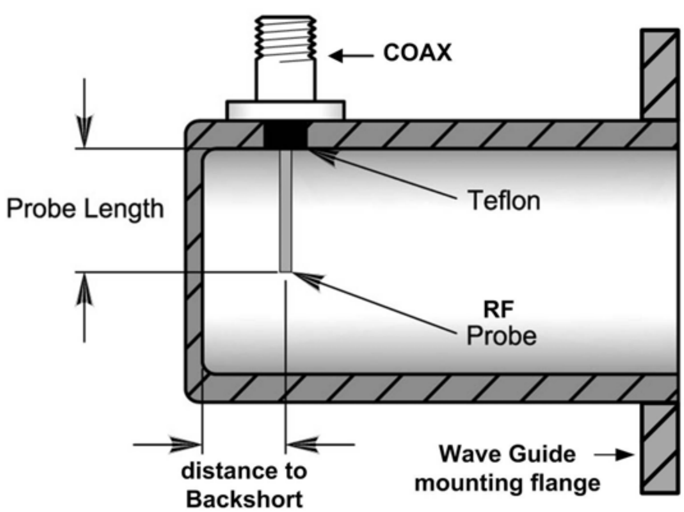

Figure 3 – Diagram of adapter used to allow Coax cable to excite the Waveguide with RF
(Courtesy of W1GHZ and ARRL QEX-2006-Nov)

Waveguide-to-COAX adapters as shown in **Fig 4** are usually fitted with either SMA or N connectors.

Figure 4 – Photograph of typical Waveguide-to-Coax Adaptor for rectangular Waveguide
(Courtesy of Robbie KB6CJZ)

Alford Slot Antenna

Hams also build UHF antennas out of metal cylinders with slots. These slotted cylinders are not waveguides and the antenna is the slot magnetic-dipole radiating omnidirectionally from the cylinder. Paul W1GHZ explains that the Alford slot is an enhanced form of the slotted-cylinder antenna.

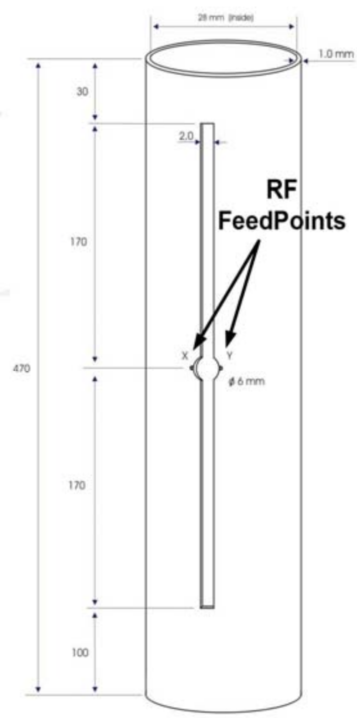

Figure 5 – Diagram of Alford Slot for 23 CMs showing RF Feedpoint in middle of slot
(Courtesy of Mijo S51KQ)

Andrew Alford enhanced the basic slot antenna, designed the Alford loop antenna and designed a number of FM and TV broadcast antennas in the mid-1940's. The Alford half-wave slot has larger dimensions than a halfwavelength wire-dipole in free space and provides gain over a dipole due to the larger aperture. A typical Alford slot has a length around four times as long as a half-wave wire-dipole, producing a gain of around 5 to 9 dBi.

There are two important construction details concerning the Alford Slot antenna. First, the impedance of a single slot is about 200 ohms. So this design requires a 4:1 balun in order to feed from 50 ohm transmitter. Usually the 4:1 balun may be too large to fit inside the cylinder, so it goes at the bottom and feedline snakes up into the cylinder. Second, the feed point for the antenna is in the center of the slot...the feed line comes up through the cylinder and then is soldered to each side of the slot (as pointed out in **Fig 5**). This looks like pretty tricky construction and soldering in my opinion. **Fig 6** shows the "inside job" handywork needed to solder to the slot.

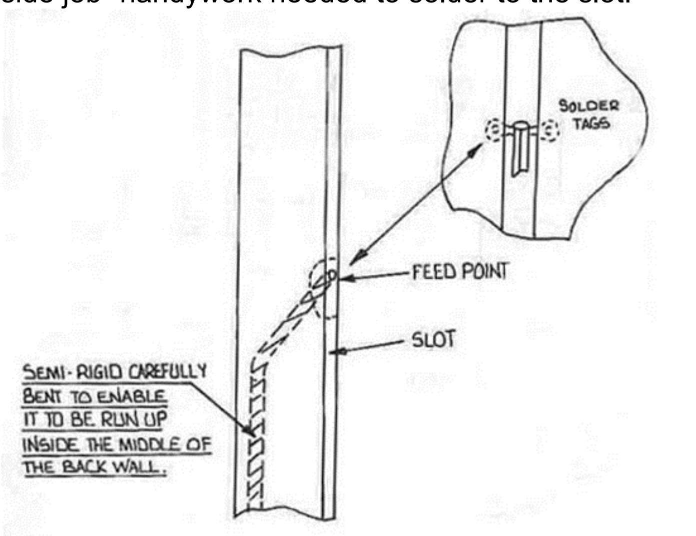

Figure 6 – Bringing the feedline up through the Cylinder of an Alford Slot antenna to solder at the slot.
(Courtesy of Mike G3JVL)

Again the RF electric-field polarization for the magnetic-field-dipole Alford Slot antenna is horizontal.

Weather-Proofing Slot Antennas

You do not want rain or snow entering the slot of either type of the two slot designs that we have discussed so far. So you typically need some type of plastic container or PVC piping to act as a radome for your antenna.

Skeleton-Slot Antenna

When I mentioned slot antennas to a friend of mine, he immediately pulled out his RSGB VHF UHF Manual by G6JP and showed me a skeleton-slot antenna for 440 MHz. G6JP explains "...further experiments showed that a thin rod bent to dimensions of 5λ/8 by 5λ/24 exhibited similar properties of a true [magnetic dipole] slot". See skeleton slot on left side of **Fig 7**.

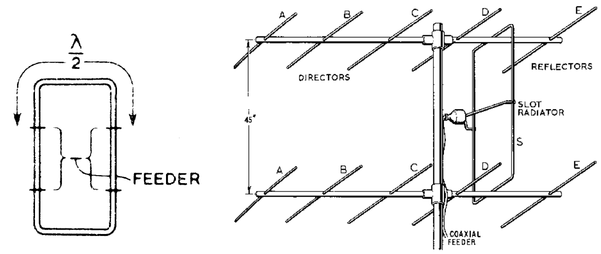

Figure 7 – Skeleton-Slot element can be used as a driven element to feed two stacked Yagi's on right
(Courtesy of RSGB VHF UHF Manual by G6JP)

I don't know…I just don't see the infinite ground plane? It seems to me like this is just a clever way to feed two stacked antennas in-phase, not a magnetic-field dipole?

Conclusions

This has been a fun article to research. I learned a lot about magnetic-dipoles, slot antennas, and microwave waveguides. The Alford Slot antenna does not seem to have a lot of gain…unless all you are looking for is a horizontal-polarized omni. The Waveguide Slot Antenna has better gain than the Alford design…but I feel like you need to have a machine shop to cut slots accurately in waveguide sections or purchase already built antennas from hams who can make them. Maybe one of the readers can explain to me more clearly why a skeleton-slot is really a thin slot in an infinite ground plane?

After this research, I think for now that I will choose a commercially available Comet 1.2 GHz model GP-21 vertical (1⁄2 wave x 21 with 14.9 dBi) for Digital-ATV.

Interesting Links

- British ATV Club – Digital-ATV and DigiLite Forums – see **www.BATC.org.UK/forum/**
- Paul W1GHZ online "Microwave Ant Handbook" – see **www.W1GHZ.org/antbook/contents.htm**
- Dan W6DFW - Waveguide Slot antenna vendor – contact **W6DFW@apex-scientific.com**
- M. Walters G3JVL article on Alford Antennas – see **www.videorepeater.co.uk/help/alford_ae.htm**
- Mijo S51KQ drawings on 23 CM Alford Slot – see **http://lea.hamradio.si/~s51kq/ANTENNA.HTM**
- K5RMG microwave group on building an Alford Slot – see **www.K5RMG.org/Alford-slot.html**
- Comet GP-21 Vertical Antenna for 1.2 GHz (imported to US by NCG) – see **www.cometantenna.com/**
- Orange County ARC newsletter entire series of DATV articles – see **www.W6ZE.org/DATV/**
- Yahoo Group for Digital ATV - see **groups.yahoo.com/group/DigitalATV/**