Antenna Workshop

The Windom Antenna...

An analysis of the Windom Antenna by Dr John Share G3OKA...who aims to dispel the myths!

In this analysis of the Windom Antenna, let's first look at its history. The design was originally published in the July 1926 issue of *QST* and credited to **Loren Windom**. The design was also due to contributions from **John Byrne**, **E. Brooke**, and **W. Everett** at the University of Illinois. There were later additions from **G2BI** and **Jim MacIntosh** from this side of the Atlantic Ocean.

Essentially, the Windom antenna is a half-wave of wire at the lowest operating frequency, running horizontally and fed by a single wire feeder, at a point one third way along its length **Fig. 1**. The theory is that this position of feed point offered the same impedance on even harmonically related frequencies.

Key Word

Harmonically related perhaps, but the key word 'buly' is often omitted in subsequent descriptions and developments. This conditional factor, that the basic premise applied only to 'even harmonics', is gradually being eroded with the passage of time. The earliest designs used open wire feeders, which operate with negligible losses even when badly matched, and it is probable that users anticipated the need for a matching unit.

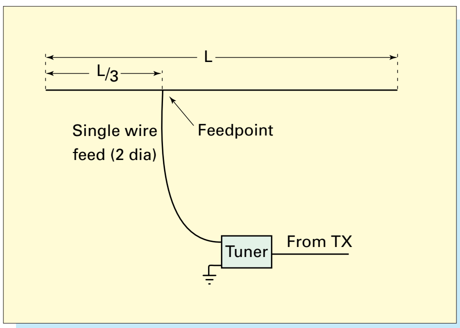

Fig. 1: The 'traditional' Windom antenna, is said to be an 'all-band' antenna, but this might not be the case, argues G3OKA.

Open wire lines are cumbersome and at some point 300Ω ladder line was substituted for the open feeder. This ladder line has a poor reputation as regard to losses and has variable characteristics when wet. Lost in the mysteries of time, it came to be accepted that the 'all-band' feed impedance was 300Ω.

In more recent times 450Ω ladder line has come to the fore. This has lower intrinsic losses and is more tolerant of rainwater, and it was inevitable that the 300Ω line would be replaced with 450Ω line. For some inexplicable reason the 'all-band' feed impedance came to be regarded as 450Ω and that, by 9:1 transformation at the antenna, 50Ω coaxial cable could be used as the feeder.

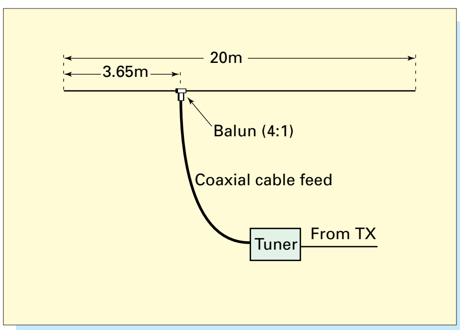

Fig. 2: An interesting combination of tapping point and wire length, that could be the ideal antenna for you!

With the ready availability of ferrite toroids, and the ease with which impedance transformers can be constructed, it became inevitable that the Windom would become an all-band antenna that would operate with a low standing wave ratio (s.w.r.) when fed with 50Ω coaxial cable'.

In Practice

In practice, the alarmingly high s.w.r. at the third harmonic of the lowest band, could be readily explained but other problems were more difficult to pin down. A whole range of different dimensions and tap point positions have at some stage of evolution been expounded as the universal solution and said to provide a low s.w.r. on all-bands.

Disappointing experiences with published designs led me to the conviction that the original tap point concept was nothing more than myth, And so, the antenna was analysed starting from first principals. The axiom of 'If it doesn't work in theory it'll never work in practice' has no conditional element and must always apply.

A length of wire that is resonant at one frequency will not be resonant on exact harmonics due to a factor termed 'end correction', that may be formulated as:

$$L = \frac{150*(N-0.05)}{f(MHz)}(m) \quad \text{or} \quad \frac{492*(N-0.05)}{f(MHz)}(ft)$$

Where N is the harmonic, (of course, when N=1 it's the fundamental) and the length, L is the resonant length of N half-waves of that harmonic. The results are tabulated in **Table 1**.

If a wire is cut to 20.35m (half-wave on 7MHz), its 28MHz band resonance is 29.105MHz. Similarly if it's cut to 21.155m (four half-waves at 28MHz) its 7MHz resonance is actually 6.743MHz.

Reactance Inductive

In this latter case the reactance of the wire at 7, 14 and 21MHz is inductive and this may be corrected by a single series capacitor to restore the wire to resonance at all frequencies. Typically, capacitor with a value of 75pF (covering 7 to 28MHz) or 150pF (covering 3.5 to 28MHz) provides a satisfactory correction. The exact value is not particularly critical.

Provided the wire is resonant, no matter how many integer half-waves it contains, the impedance at any point, anywhere along it entire length will always be purely resistive. However, the value of this impedance depends on the number of integer half-waves and the specific electrical angle of the antenna current at that point.

Tables of the impedance at current nodes (R_n) for various numbers of half-waves are readily available. Over the range of particular interest they may be summarised as follows:

N=1	R_n=73Ω
N=2	R_n=94Ω
N=3	R_n=106Ω
N=4	R_n=115Ω

Table 1

Frequency (MHz)	Harmonic (N)	Length (L)
7.0	1	20.350m (66.770ft)
14.0	2	20.887m (68.528ft)
21.0	3	21.065m (69.114ft)
28.0	4	21.155m (69.407ft)

● Tabulating resonant lengths for the different harmonics on a single wire.

Moving away from the current node the impedance increases in a sinewave form until, logically, it approaches infinity at the open end of the wire. It should be obvious that this must be a voltage node, there is nowhere for the current to flow hence the current must be zero.

Electrical Length

The relationship between feed point impedance (R_p) and electrical length (F) in degrees is expressed as

$F = \cos^{-1} \{(R_n/R_p)-0.5\}$

Most scientific calculators have the inverse trigonometric function ($\sin^{-1}$, $\cos^{-1}$ and $\tan^{-1}$), but computers tend to provide only the ArcTan ($\tan^{-1}$) function, from which it's possible to derive other trigonometric functions. In the BASIC computer language you could use the following series of statements:

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B= SQR(Rn/Rp) :
A= SQR(1-B^2)
X=ATN (A/B) * (180 / 3.1416)
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The resultant value for X is an angle (F) expressed in degrees.

As an example, consider a 20m long wire, a frequency of 14MHz and a desired tap point impedance of 200Ω. From the table N=2 therefore R_n = 94Ω and the equation evaluates to 46.71°. A quarter-wave at 14MHz can be assumed to be 5m.

A 200Ω tap position is located either side of the current node at a distance of :

(F/90) * (l/4) metres.

In the above example, the tap point equates to {(46.71/ 90) * 5}m = 2.6m. So, a 200Ω tap position will occur at (**5.0-2.6**)m and again at (**5.0+2.6**)m from the end of the wire.

Suffer Loss

All feeders suffer loss along their length, even when correctly matched. This loss occurs in both forward and reverse directions. Also, the losses are considerably higher when there is a severe mismatch at the load. The return loss masks the actual load mismatch so, that at the source end there's a lower s.w.r. reading than that occurring at the load feed-point.

So, we can use this loss reducing s.w.r. reading to our advantage. By accepting a maximum tolerable s.w.r. at the source, we can calculate a wider range of mismatch at the antenna, knowing that some of this mismatch will be hidden by the return losses in the feeder.

Accepting that a mismatch at the antenna is tolerable it remains only to define the limits. When we transform the cable impedance to a higher antenna impedance a significant range of values become available for consideration. When using a 50Ω coaxial cable coupled with a 4:1 balun, the ideal design antenna impedance will be 200Ω.

If we take a 10% variation in this ideal impedance value, (a range of 180-220Ω) there will not be a significant change noticeable at the source end. Similarly using a 6:1 balun, a 300Ω impedance becomes 270-330Ω, and for a 9:1 balun, 450Ω can be range over 410-490Ω.

Lost Appeal

Air cored impedance transformers have long lost their appeal, though they do find favour in high power installations. Compact ferrite toroidal baluns now dominate and can be relied upon to function correctly even when quite crudely made.

The greatest losses in ferrite cored baluns occur at the highest frequency. So, for instance, inexplicably poor s.w.r. at 28MHz is usually traceable to a Ferrite Toroidal transformer that's not functioning according to its design specification.

A 4:1 impedance 'auto-transformer' balun, comprising two identical windings formed into a lightly twisted pair, will generally operate over a 10:1 frequency range (3-30MHz) with minimal losses.

A trifilliar wound auto-transformer balun with the ratio of (2+2+1) turns, results in a transformation ratio of 6.25:1. Whilst using the turns ratio of (1+1+1) gives an impedance ratio of 9:1. But these later cases can prove disappointing in terms of frequency range and efficiency.

Now, having established a technique to compensate for end factor correction, determining the impedance at any point of the wire, and a means of transforming 50Ω cable to higher values it only remains evaluate dimensions to find that elusive 'All-band Antenna'.

Whilst using a calculator to repetitively calculate the values, we will arrive at the same results, this effort cannot be justified. A computer can repeatedly perform the calculations needed very quickly, using a range of parameters and graphically display the result.

Primitive Program

Even a primitive computer program, written in *QBASIC* that ignores end factor correction in multiple half-waves, as well as using a gross approximation for quarter waves will work. The results will confirm that, even at this level of precision and irrespective of the impedance, no single tap point will give the same impedance, even for two frequencies.

Sometime, reverse engineering a design, by analysing published dimensions is quite interesting. It's necessary to determine the angle at the tap point and then calculate the impedance.

Consider a nominal 20m wire with a tap point at 7.62m from one end. It's necessary to roughly work out where the current nodes will occur and determine the distance of the tap from the node

Operating at 7MHz with a λ/4 = 10m, and the tap is 2.38m from the current node (10.0 – 7.62). As it's a single half-wave, then N=1 hence R_n= 73Ω.

F = {90*(10-7.62)}/10 = 21.42°

cc = cos(F) :

cd = cc^2 :

The impedance = R_n/cd, giving a result of about 85Ω at 7MHz.

When the 21MHz case is investigated the 20m becomes three half-waves so, N=3, R_n= 106Ω, the current nodes occur at 3.35m and 10m from the end of the wire. The tap point is 2.43m from the current node at 10m and a quarter wave is now 3.35m.

F = {90*(10-7.62)}/3.35 = 63.94°

cc = cos(F) :

cd = cc^2 :

The impedance = R_n/cd, giving a result of about 550Ω at 21MHz.

...is it any good?

In Conclusion

So, having looked at the above figures, what can we say in conclusion? We can say, that there are combinations where tolerable multi-band matches do occur, such as the one shown in **Fig. 2**. A 4:1 balun fed 20m wire with a tap at 3.65m from one end, it's an interesting combination with an s.w.r. of 2:1 or below on 7, 14, 21 and 28MHz.

There are other combinations to be rediscovered by applying the above analysis. **However a 20m wire with the tap at 6.66m (the exact one third point) is one combination that should be avoided.**

As the basis for an 'all-band antenna', the one third tap theory, ' offering the same impedance' on all bands should be consigned to the realms of myth where it belongs! PW