

ON MULTI-WIRE FAN MONOPOLE ANTENNAS

Igor Grigorov, RK3ZK [reference article entitled *“The Broadband Vertical Asymmetrical Antenna”* in the November 2001 issue of *antenneX*] has revisited multi-wire fan antenna systems. As background he references two articles written by Matiychenko, UW4HW and John Schultyz, W2EEY, published in popular radio amateur literature in 1968. But multi-wire fan antennas have been used much earlier, dating in fact to the turn of the last century. For example Marconi used a 54-wire fan with his sender at Poldhu, Cornwall, for his first transatlantic experiment in December 1901 --- his receiver was located on Signal Hill, Newfoundland.

I have experimentally and numerically modeled 2-, 3-, 5-, 7-, 12-, 24- and 54-wire fans --- fan shape similar to the antenna system used by Marconi [John S. Belrose, *“Revisiting Wire Aerials at the Turn of the Century”*, *Proceedings of the Fourth International Symposium on Antennas and EM Theory, Xi’an, China, 1997, pp. 73-78*]. The purpose of this study was to determine the frequency used for Marconi’s first transatlantic experiment*.

A multi-wire fan antenna, see **Figure 1**, with the ends of the sloping wires **connected** at the top, is a much more complicated antenna system than suggested by what Igor has written. And, it is not a broadband antenna, at least the wire versions that I have studied. The antenna’s input impedance vs. frequency response is complicated by the fact that both antenna mode and transmission line mode currents can flow on the structure. The transmission line mode currents flow around the 8-triangular loops formed by the wires of differing lengths.

If the ends of the sloping wires **are not connected**, the antenna response is simple. Resonance is determined by the lengths of the sloping wires --- and an antenna can easily be constructed that will resonate on several amateur bands (as Igor has suggested). The only complication is that some frequencies may excite resonance in two wires, e.g. a 21 MHz frequency will excite a resonance in a wire dimensioned for this frequency, as well in a wire dimensioned for 7 MHz, since this wire is 3/4 wavelength long for the 21 MHz frequency.

For this Technical Note (TN) I have modeled (using NEC-4D) the 9-wire fan (see **Figure 1**) dimensioned as in Igor’s article. To determine the radiation characteristics I have assumed for this TN a PEC ground. The SWR vs. frequency response (see

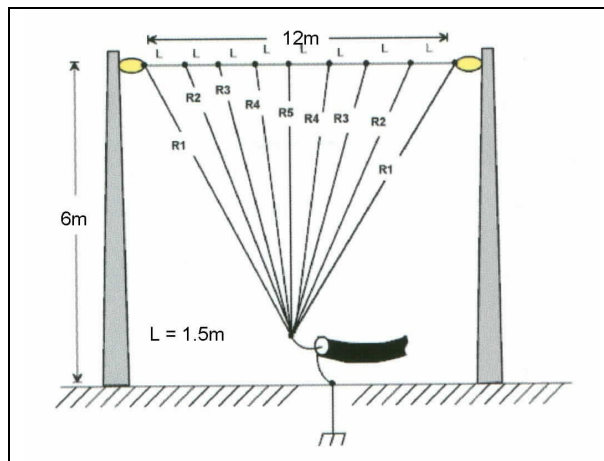


Figure 1 Igor’s Sketch of a 9-Wire Fan monopole type antenna with wooden support poles.

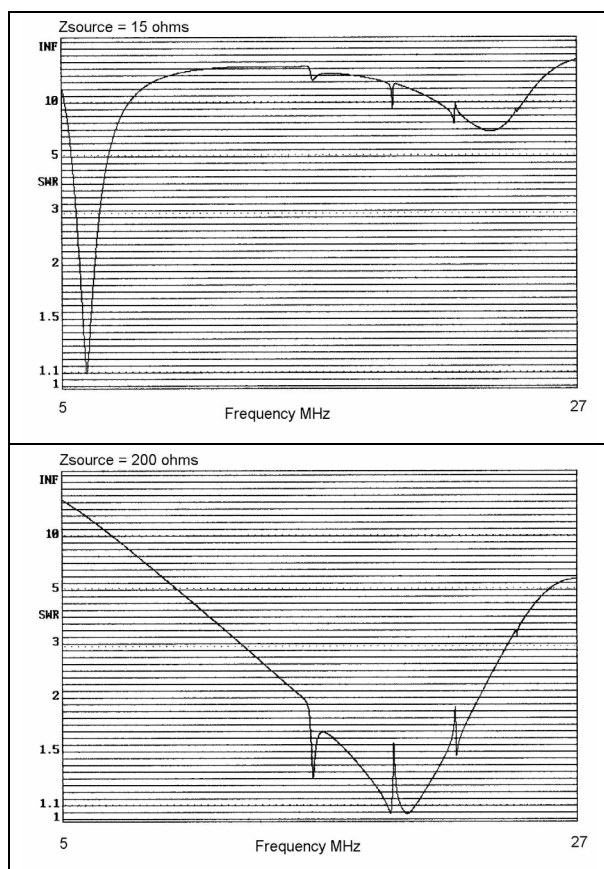


Figure 2 SWR vs. frequency (5 – 27 MHz) for **Figure 1**’s antenna, for two source impedances: 15 ohms and 200 ohms. Note: PEC ground.

Figure 2 upper curve) implies a resonance (low SWR) at only one frequency (6 MHz) for $Z_{\text{source}} = 15$ ohms (that is Z_{source} low).

The inductive reactance of the antenna's impedance is low at 6 MHz and 19.8 MHz (see **Table 1**). Hence if $Z_{\text{source}} = 200$ ohms, the SWR is low at 19.8 MHz (the lower curve in Figure 2).

Table 1

Impedance vs. frequency for **Figure 1's** antenna over a PEC ground.

Frequency MHz	Impedance $R_a + j X_a$
6	$14 + j 1.4$
8	$28 + j 59$
10	$55 + j 111$
12	$100 + j 154$
14	$171 + j 172$
16	$214 + j 107$
19.8	$193 + j 6$
22	$123 + j 8$
24	$71 + j 49$
26	$53 + j 114$

Sharply resonant responses are found at 15.7, 19.1, 21.8 and 24.4 MHz --- see **Figure 2**. These sharp resonant responses are the transmission line mode resonances referred to above.

The antenna appears to be broadly anti-resonant (high SWR) at frequencies between 6 and 20 MHz (see upper curve in **Figure 1**), but the reactive component of the input impedance does not pass through zero. The antenna is inductive (according to NEC-4) for all frequencies > 6 MHz, see **Table 1**.

The azimuthal radiation pattern (not shown) changes from an omni-directional pattern for frequencies near the low end of the band, to broadside directivity at 20 MHz. At 27 MHz the directivity is a maximum in the plane of the antenna (minor lobes in the orthogonal directions).

The vertical plane principle plane radiation pattern is cosinusoidal at the low end of the band. High angle lobes start to develop at a frequency of about 21 MHz. While the principle pattern lobe is directed toward the horizon for the above range of frequencies (5 – 27 MHz) for very very good ground conductivity (sea water) in front of the antenna, the elevation angle for maximum gain (take-off angle) decreases rapidly with increase in frequency, for frequencies near the high end of the band. For

vertically polarized antennas over real ground the efficiency is particularly poor if the take-off angle decreases to 10° or less. This fan antenna is therefore not a very useful radiator at frequencies near the high end of the band. At 27 MHz the take off angle is 6° for seawater conductivity. For average ground in front of the antenna (5 mS/m, 13) the low angle lobe is heavily attenuated, and the high angle lobes dominate the vertical plane pattern (see **Figure 3**).

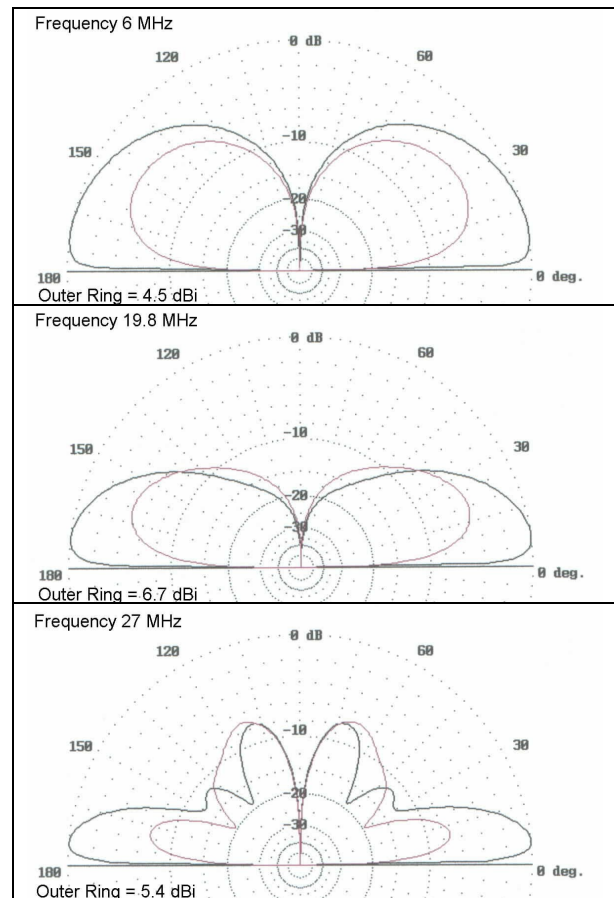


Figure 3 Principle plane, vertical plane patterns for 6-, 19.8- and 27 MHz for a well grounded antenna with sea water (black maximum gain trace) and average ground (red trace) in front of the antenna.

Finally, a word of caution for antenna modellers: MININEC and NEC-4 can have a problem in modelling a single wire feed feeding many wires (the source is on the single wire). And, NEC-2 should not be used, since at the junction NEC-2 considers only the radius of each wire. This program does not take into account the charge distribution due to currents flowing on adjacent wires. NEC-4 and MININEC use a quasistatic approximation taking account of

neighboring wires, so should do better. My study did not establish guidelines for modelling multi-wire fans. All I can say is that I found excellent agreement between my experimental and numerical models (for both antenna mode and transmission line mode responses) for fans comprising only a few wires. The agreement between experiment and simulation becomes worse with increase in frequency.

Conclusions: A multi-wire fan is not a broadband antenna. But the maximum excursion in impedance is reduced compared with a wire or a tower monopole. If one wants a vertically polarized HF or VHF/ UHF broadband wire/or rod antenna the **disc-cone antenna** is perhaps one of the better antenna types [John S. Belrose, "The HF Discone Antenna", *QST*, July 1975, pp. 11-14, 56]. The broad bandwidth results from the radial symmetry in the antenna system. Currents flowing outward on the disc

and downward on the wires forming the cone, excite resonance when the vertical distance between the disc and the cone at a particular frequency is a quarter wavelength. This antenna can have a 15:1 bandwidth (low SWR referenced to 50 ohms), but the low angle lobe starts to lift off the horizon for frequencies greater than about 3:1 (bi-conical horn effect).

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** [John S. Belrose, "A Radioscientist's Reaction to Marconi's first transatlantic Wireless Experiment – Revisited", IEEE APS/URSI Meeting, Boston, MA, July 2001].*

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