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The Open-Sleeve Antenna

Although only recently adapted for the HF and VHF amateur bands, the open-sleeve antenna has been around since 1946. The antenna was invented by Dr J. T. Bolljahn, of Stanford Research Institute. This section on sleeve antennas was written by Roger A. Cox, WBØDGF.

The basic form of the open-sleeve monopole is shown in **Fig 33**. The open-sleeve monopole consists of a base-fed central monopole with two parallel closely spaced parasitics, one on each side of the central element, and grounded at each base. The lengths of the parasitics are roughly one half that of the central monopole.

Impedance

The operation of the open sleeve can be divided into two modes, an antenna-mode and a transmission-line mode. This is shown in **Fig 34**.

The antenna-mode impedance, Z_A, is determined by the length and diameter of the central monopole. For sleeve lengths less than that of the monopole, this impedance is essentially independent of the sleeve dimensions.

The transmission-line mode impedance, Z_T, is determined by the characteristic impedance, end impedance, and length of the 3- wire transmission line formed by the central monopole and the two sleeve elements. The characteristic impedance, Z_c, can be determined by the element diameters and spacing if all element diameters are equal, and is found from

$$Z_c = 207 \log 1.59 (D/d) \qquad \text{(Eq 2)}$$

where

D = spacing between the center of each sleeve element and the center of the driven element

d = diameter of each element

This is shown graphically in **Fig 35**. However, since the end impedance is usually unknown, there is little need to know the characteristic impedance. The transmission-line mode impedance, Z_T, is usually determined by an educated guess and experimentation.

As an example, let us consider the case where the central monopole is $\lambda/4$ at 14 MHz. It would have an antenna mode impedance, Z_A, of approximately 52 Ω, depending upon the ground conductivity and number of radials. If two sleeve elements were added on either side of the central monopole, with each approximately half the height of the monopole and at a distance equal to their height, there would be very little

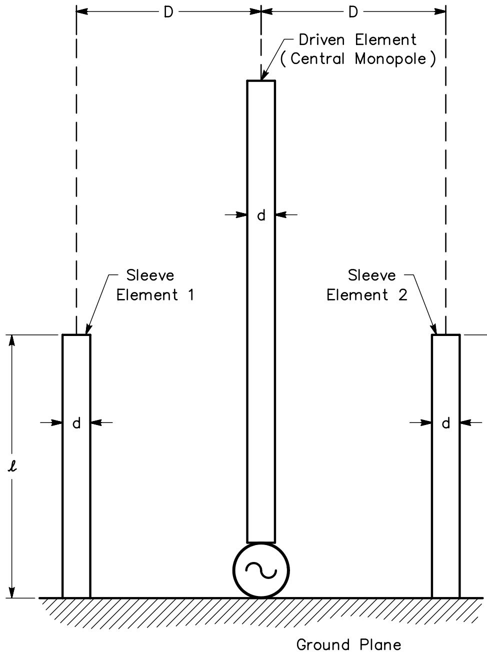

Fig 33—Diagram of an open-sleeve monopole.

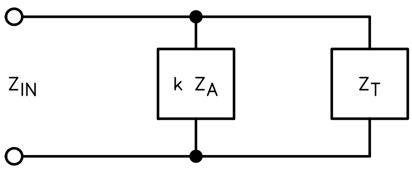

Fig 34—Equivalent circuit of an open-sleeve antenna.

effect on the antenna mode impedance, Z_A, at 14 MHz.

Also, Z_T at 14 MHz would be the end impedance transformed through a λ/8 section of a very high characteristic impedance transmission line. Therefore, Z_T would be on the order of 500-2000 Ω resistive plus a large capacitive reactance component. This high impedance in parallel with 52 Ω would still give a resultant impedance close to 52 Ω.

At a frequency of 28 MHz, however, Z_A is that of an end-fed half-wave antenna, and is on the order of 1000-5000 Ω resistive. Also, Z_T at 28 MHz would be on the order of 1000 to 5000 Ω resistive, since it is the end impedance of the sleeve elements transformed through a quarter-wave section of a very high characteristic impedance 3-wire transmission line. Therefore, the parallel combination of Z_A and Z_T would still be on the order of 500 to 2500 Ω resistive.

If the sleeve elements were brought closer to the central monopole such that the ratio of the spacing to element diameter was less than 10:1, then the characteristic impedance of the 3-wire transmission line would drop to less than 250 Ω. At 28 MHz, Z_A remains essentially unchanged, while Z_T begins to edge closer to 52 Ω as the spacing is reduced. At some particular spacing the characteristic impedance, as determined by the D/d ratio, is just right to transform the end impedance to exactly 52 Ω at some frequency. Also, as the spacing is decreased, the frequency where the impedance is purely resistive gradually increases.

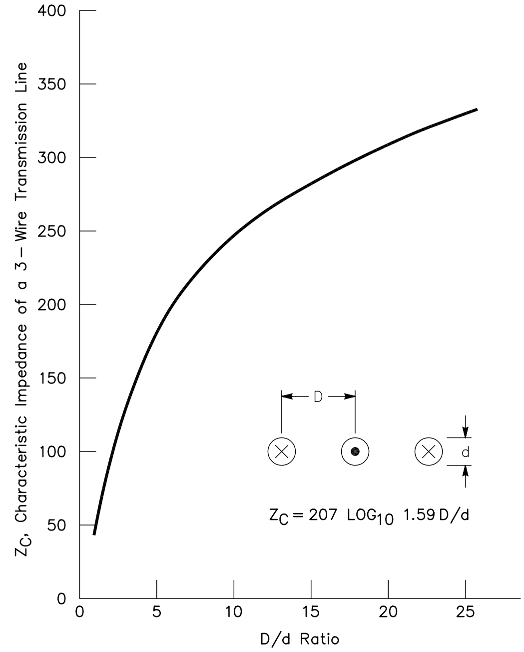

Fig 35—Characteristic impedance of transmission-line mode in an open-sleeve antenna.

The actual impedance plots of a 14/28-MHz open-sleeve monopole appear in **Figs 36** and **37**. The length of the central monopole is 195.5 inches, and of the sleeve elements 89.5 inches. The element diameters range from 1.25 inches at the bases to 0.875 inch at each tip. The measured impedance of the 14-MHz monopole alone, curve A of Fig 36, is quite high. This is probably because of a very poor ground plane under the antenna. The addition of the sleeve elements raises this impedance slightly, curves B, C and D.

As curves A and B in Fig 37 show, an 8-inch sleeve spacing gives a resonance near 27.8 MHz at 70 Ω, while a 6-inch spacing gives a resonance near 28.5 MHz at 42 Ω. Closer spacings give lower impedances and higher resonances. The optimum spacing for this particular antenna would be somewhere between 6 and 8 inches. Once the spacing is found, the lengths of the sleeve elements can be tweaked slightly for a choice of resonant frequency.

In other frequency combinations such as 10/21, 10/24, 14/21 and 14/24-MHz, spacings in the 6 to 10-inch range work very well with element diameters in the 0.5 to 1.25-inch range.

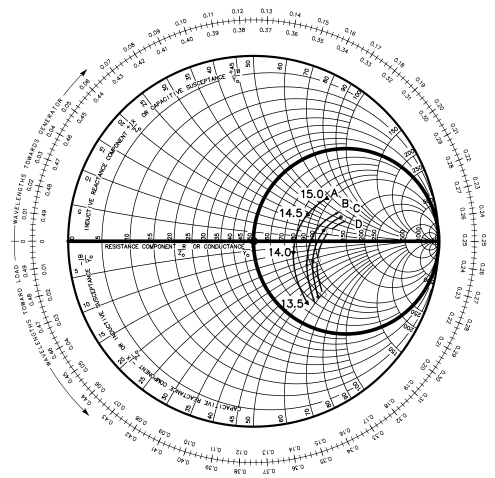

Fig 36—Impedance of an open-sleeve monopole for the frequency range 13.5-15 MHz. Curve A is for a 14 MHz monopole alone. For curves B, C and D, the respective spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches. See text for other dimensions.

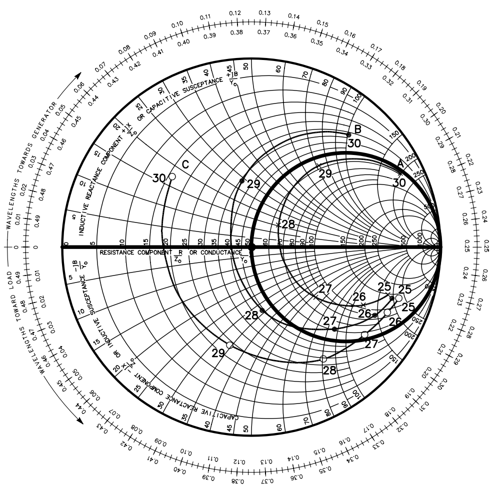

Fig 37—Impedance of the open-sleeve monopole for the range 25-30 MHz. For curves A, B and C the spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches, respectively.

Bandwidth

The open-sleeve antenna, when used as a multiband antenna, does not exhibit broad SWR bandwidths unless, of course, the two bands are very close together. For example, **Fig 38** shows the return loss and SWR of a single 10-MHz vertical antenna. Its 2:1 SWR bandwidth is 1.5 MHz, from 9.8 to 11.3 MHz. Return loss and SWR are related as given by the following equation.

$$SWR = \frac{1+k}{1-k} \qquad \text{(Eq 3)}$$

where

$$k = 10^{\frac{R_L}{20}}$$

RL = return loss, dB

When sleeve elements are added for a resonance near 22 MHz, the 2:1 SWR bandwidth at 10 MHz is still nearly 1.5 MHz, as shown in **Fig 39**. The total amount of spectrum under 2:1 SWR increases, of course, because of the additional band, but the individual bandwidths of each resonance are virtually unaffected.

The open-sleeve antenna, however, can be used as a broadband structure, if the resonances are close enough to overlap. With the proper choices of resonant frequencies, sleeve and driven element diameters and sleeve spacing, the SWR "hump" between resonances can be reduced to a value less than 3:1. This is shown in **Fig 40**.

Current Distribution

According to H. B. Barkley (see Bibliography at the end of this chapter), the total current flowing into the base of the open-sleeve antenna may be broken down into two components, that contributed by the antenna mode, I_A, and that contributed by the transmission-line mode, I_T. Assuming that the sleeves are approximately half the height of the central monopole, the impedance of the antenna mode, Z_A, is very low at the resonant frequency of the central monopole, and

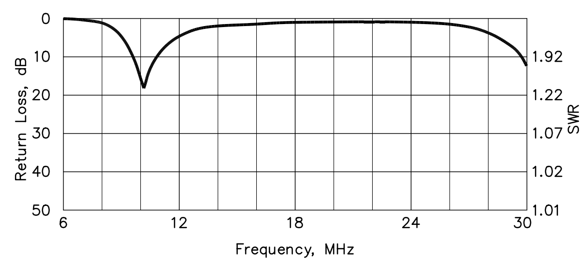

Fig 38—Return loss and SWR of a 10 MHz vertical antenna. A return loss of 0 dB represents an SWR of infinity. The text contains an equation for converting return loss to an SWR value.

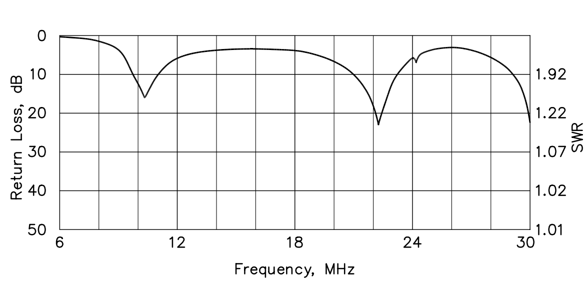

Fig 39—Return loss and SWR of a 10/22 MHz open-sleeve vertical antenna.

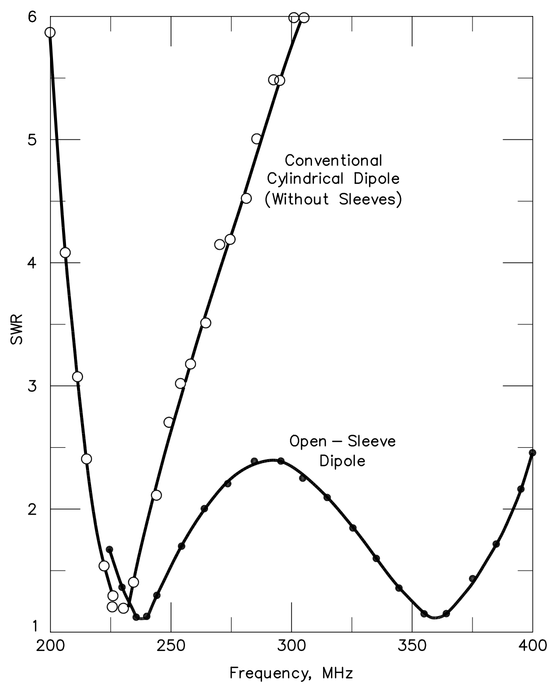

Fig 40—SWR response of an open-sleeve dipole and a conventional dipole.

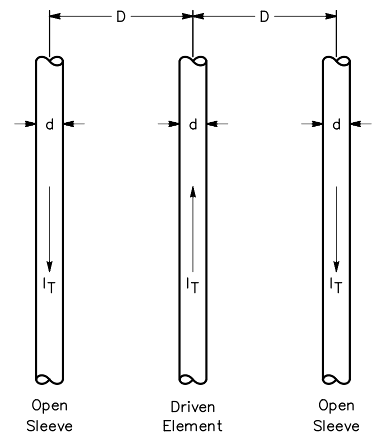

Fig 41—Current distribution in the transmission-line mode. The amplitude of the current induced in each sleeve element equals that of the current in the central element but the phases are opposite, as shown.

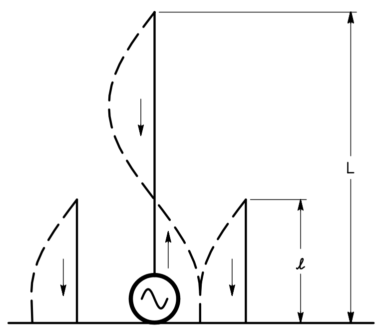

Fig 42—Total current distribution with λ= L/2.

the impedance of the transmission-line mode, Z_T, is very high. This allows almost all of the current to flow in the antenna mode, and I_A is very much greater than I_T. Therefore, the current on the central λ/4 monopole assumes the standard sinusoidal variation, and the radiation and gain characteristics are much like those of a normal λ/4 vertical antenna.

However, at the resonant frequency of the sleeves, the impedance of the central monopole is that of an end fed half-wave monopole and is very high. Therefore I_A is small. If proper element diameters and spacings have been used to match the transmission line mode impedance, Z_T, to 52 Ω, then I_T, the transmission line mode current, is high compared to I_A.

This means that very little current flows in the central monopole above the tops of the sleeve elements, and the radiation is mostly from the transmission-line mode current, I_T, in all three elements below the tops of the sleeve elements. The resulting current distribution is shown in **Figs 41** and **42** for this case.

Radiation Pattern and Gain

The current distribution of the open-sleeve antenna where all three elements are nearly equal in length is nearly that of a single monopole antenna. If, at a particular frequency, the elements are approximately λ/4 long, the current distribution is sinusoidal.

If, for this and other length ratios, the chosen diameters and spacings are such that the two sleeve elements approach an interelement spacing of λ/8, the azimuthal pattern will show directivity typical of two in-phase vertical radiators, approximately λ/8 apart. If a bi-directional pattern is needed, then this is one way to achieve it.

Spacings closer than this will produce nearly circular azimuthal radiation patterns. Practical designs in the 10 to 30 MHz range using 0.5 to 1.5-inch diameter elements will produce azimuthal patterns that vary less than ±1 dB.

If the ratio of the length of the central monopole to the length of the sleeves approaches 2:1, then the elevation pattern of the open-sleeve vertical antenna at the resonant frequency of the sleeves becomes slightly compressed. This is because of the in-phase contribution of radiation from the λ/2 central monopole.

As shown in **Fig 43**, the 10/21-Mhz open-sleeve vertical antenna produces a lower angle of radiation at 21.2 MHz with a corresponding increase in gain of 0.66 dB over that of the 10-MHz vertical alone. At length ratios approaching 3:1, the

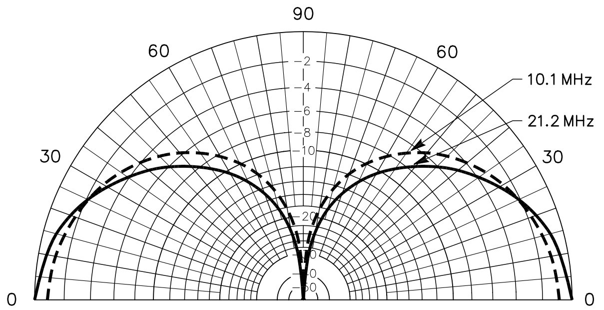

Fig 43—Vertical-plane radiation patterns of a 10/21-MHz open-sleeve vertical antenna on a perfect ground plane. At 10.1 MHz the maximum gain is 5.09 dBi, and 5.75 dBi at 21.2 MHz.

antenna mode and transmission-line mode impedance become nearly equal again, and the central monopole again carries a significant portion of the antenna current. The radiation from the top λ/2 combines constructively with the radiation from the λ/4 sleeve elements to produce gains of up to 3 dB more than just a quarter-wave vertical element alone.

Length ratios in excess of 3.2:1 produce higher level sidelobes and less gain on the horizon, except for narrow spots near the even ratios of 4:1, 6:1, 8:1, etc. These are where the central monopole is an even multiple of a half-wave, and the antenna-mode impedance is too high to allow much antenna-mode current.

Up to this point, it has been assumed that only λ/4 resonance could be used on the sleeve elements. The third, fifth, and seventh-order resonances of the sleeve elements and the central monopole element can be used, but their radiation patterns normally consist of high-elevation lobes, and the gain on the horizon is less than that of a λ/4 vertical.

Practical Construction and Evaluation

The open-sleeve antenna lends itself very easily to home construction. For the open-sleeve vertical antenna, only a feed-point insulator and a good supply of aluminum tubing are needed. No special traps or matching networks are required. The open-sleeve vertical can produce up to 3 dB more gain than a conventional λ/4 vertical. Further, there is no reduction in bandwidth, because there are no loading coils.

The open-sleeve design can also be adapted to horizontal dipole and beam antennas for HF, VHF and UHF. A good example of this is Telex/Hy-Gain's Explorer 14 triband beam which utilizes an open sleeve for the 10/15-meter driven element. The open-sleeve antenna is also very easy to model in computer programs such as *NEC* and *MININEC*, because of the open tubular construction and lack of traps or other intricate structures.

In conclusion, the open-sleeve antenna is an antenna experimenters delight. It is not difficult to match or construct, and it makes an ideal broadband or multiband antenna.