Coaxial Transmission Lines
Bead supported ones

G.Sankar, GMRT–TIFR, Pune. 4th May,1991.

---

1 Introduction :

Insulating beads are used to support the center–conductor of an air–dielectric coaxial line. These beads will introduce discontinuities and, if not properly designed, can produce large reflection losses. The design procedure for these support beads depends upon the frequency range of application. A wide–band range will rquire more complex design.
In this report, two types of bead–supports are investigated for 327 MHz dipole design. The first one is the simpler design called as '**spaced pair** ' and the second one is the '**compensated undercut**' type.

2 Spaced Pair Beads :

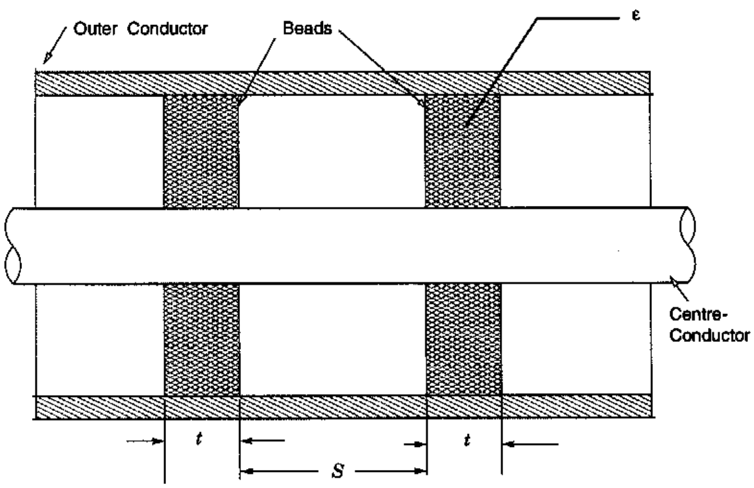

Fig. 1.

The beads of thickness t each, separated by a distance $(S+t)$ between their centres (as shown in Fig.1) is related to the wavelength λ by

$$\tan \beta S = \frac{2\sqrt{\epsilon}}{(1+\epsilon)} \cdot \cot \beta t \sqrt{\epsilon} \quad (1)$$

where ϵ is the dielectric constant of the bead's material and β is given by

$$\beta = \frac{2\pi}{\lambda}$$

Solving S, for various thicknesses of the bead t, we get (for the chosen frequency of 327 MHz; $\lambda = 916.82$ mm.) and $\epsilon = 2.04$ for Teflon beads ...

t (mm.)	S (mm.)
3.0	224.3
5.0	221.1
6.0	219.5
10.0	213.0
20.0	196.8

Either the 6 mm. or 20 mm. beads' thickness would suffice our requirement since the coaxial transmission line length is a little above $\lambda/4$. (vide.Ref.[1])

3 Compensated Undercut Beads :

The centre–conductor is given a step–like–recess to fit the bead, as shown in Fig.2. This exhibits better frequency characteristics, and compensates fringing capacitance at undercut region, which in turn exhibits low reflections at lower frequencies. The expression for thickness t_0 of the bead is :

$$\tan \beta t_0 = \frac{4\pi f C Z_{OB}}{(4\pi f C Z_{OB})^2 + (Z_{OB}/Z_0)^2 - 1} \quad (2)$$

where

$$\beta = \frac{2\pi\sqrt{\epsilon}}{\lambda} \quad (3)$$

and

$$Z_{OB} = \frac{138}{\sqrt{\epsilon}} \cdot \log \frac{D_o}{D_i} \quad (4)$$

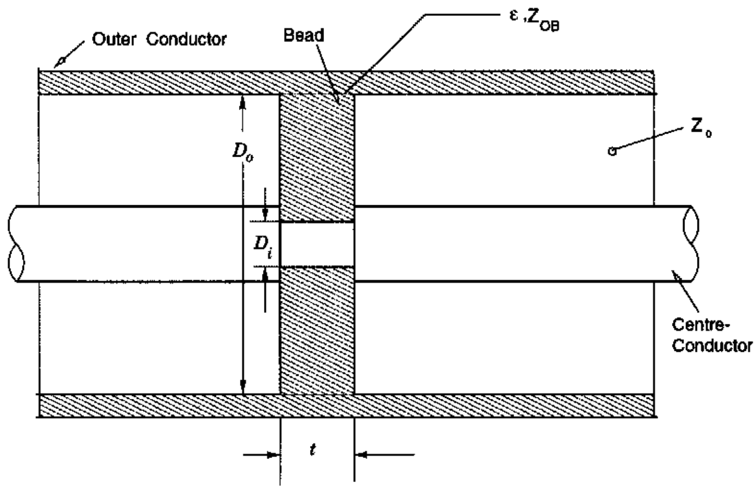

Fig. 2.

D_o and D_i are diameters of the bead, as shown in Fig.2. The C is the fringing capacitance at the undercut region.

An expression for the fringing capacitance can be arrived at ,as shown in Ref.[2]; the capacitive discontinuities at the abrupt change in diameter of the centre–conductor can be found ,if the discontinuities are separated by t_0 satisfies:
$t_0 \geq b_1$, where b_1 is the annular gap as shown in Fig.3.

The capcitance at the discontinuity C_1 is given by

$$C_1 = 2\pi r_1 \epsilon_d C_d(\alpha) \tag{5}$$

where

$$\alpha = \frac{a_1}{b_1} \tag{6}$$

and $C_d(\alpha)$ is a function of α :

$$C_d(\alpha) \simeq 0.001439(\alpha^{-2} + \alpha^{-1}) \tag{7}$$

A more accurate value of $C_d(\alpha)$ could be obtained if one does interpolation of the $C_d(\alpha)$ vs. α curve, depicted in Fig.42–10 (page:42–17) of Ref.[1].

4 Examples :

Consider a bead of $D_o = 12.7$ mm. and $D_i = 5.5$ mm. Then a_1 will be $(D_o - D_i)/2$, which makes $a_1 = 3.6$ mm.

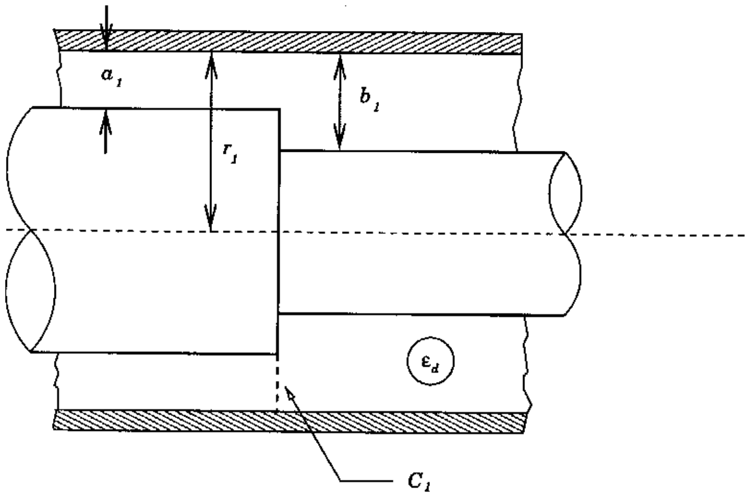

Fig. 3.

For an undercut dia. of 4.5 mm. of the centre–conductor,b_1 will be $a_1 + (5.5 - 4.5)/2$, i.e., $b_1 = 4.1$ mm. Then $\alpha = 0.8781$ and the corresponding $C_d(\alpha)$ value (by interpolation) is 0.0022 $\mu\mu$f/cm. Hence

$$\begin{aligned} C_1 &= 2\pi \times 0.635 \times 2.04 \times 0.0022 \mu\mu f \\ &= 0.01791\ \mu\mu f. \end{aligned}$$

The bead's impedance Z_{OB},

$$\begin{aligned} Z_{OB} &= 138/\sqrt{2.04} \times log(12.7/4.5) \\ &= 43.5358\ \Omega \end{aligned}$$

Then $(Z_{OB}/Z_0)^2 = 0.7534724$, since $Z_0 = 50.155\,\Omega$. Substituting all in Eqn.1, $tan(\beta t_0) = -0.012997$ and $\beta = 9.788386 \times 10^{-3}$, $t_0 = 1.33$ mm. which is less than b_1. The above–said condition of capacitive discontinuity is not satisfied here. Let us investigate for a deeper under–cut bead next.

Suppose $b_1 = 3.85$ mm. for the same centre–conductor dia. of 5.5 mm, (i.e. $a_1 = 3.6$ mm.) $\alpha = 0.935065$; $C_d = 0.0011357\,\mu\mu$f and $C_1 = 0.009244\,\mu\mu$f ; $Z_{OB} = 39.11476\,\Omega$ From Eqn.(1), $tan(\beta t_0) = 0.037968$ or $t_0 = 3.88$ mm.

Here $t_0 > b_1$, and hence this is a viable design for compensated undercut bead for coaxial transmission line.

The only negative point for such design when compared to the spaced– pair design is that the requirement of precise machining and fitting jobs required for the former. The existing design of 327 MHz. dipole employs the **spaced pair** only for bead–support.

5 References :

1. Johnson & Jasik (Eds.) **Antenna Engineering Handbook**,McGraw Hill Book Co., 1984 Edition; pp.42–15 to 42–17.

2. G.L.Ragan (Ed.) **Microwave Transmission Circuits**, Dover Publ., New York., 1948.

* *** ***** *** *