Correspondence

Analysis of Split Coaxial Line Type Balun*

Since the split coaxial type balun was developed, it has been widely utilized as a microwave radiator with dipole, and a duplexer of television transmitting unit for its superior working capacity. There are several papers[1-3] on the analytical theory of this balancing unit. But, strictly speaking, there are still some points remaining to be rescrutinized, such as the radiator receiving the effect of the split coaxial and its lines from the earth.

We have not thoroughly discussed how the input admittance will change with the balancing of the load and the unequally divided cylinder, or what effects the admittance will have between the outer and split conductors, when it is utilized as a duplexer.

Split Coaxial Type Balun

We will consider the problem on the split coaxial type balun which is cut in two sections and has a dipole between each segment of the outer cylinder, as shown in Fig. 1. This type of balun has a special character which does not cause any earth current, compared with the other types. But, when it is divided unsymmetrically, the character will not work. In practical use, it is impossible to make it completely symmetrical. Furthermore, if we use it in the arbitrary split, it will be utilized as a matching element because the variable transform ratio is derived. In such a case, the earth effect will be taken into account for the input impedance.

Generally, the antenna load forms the distributed circuit, but we can analyze it by using the simplified theory, replacing it with the equivalent concentric constant. An actual circuit is shown in Fig. 2, where the load is symmetrical, Y is the admittance inserted between terminals 1 and 2 directly, Y_1 and Y_2 are the admittances inserted through the earth, and Y_3 is the admittance existing between the coaxial line and the earth measured from the right boundary surface. Input impedance can be calculated as follows:

$$Y_{\text{in}} = \frac{i_1}{v_1} = \frac{1}{\alpha^2}\Big\{ Y + Y_s + Y_1(1-\alpha) + \frac{[Y_2\alpha - Y_1(1-\alpha)](Y_1 + \alpha Y_3)}{Y_1 + Y_2 + Y_3} \Big\}$$

where $Y_s = jY_{s0} \cot \beta l$ and Y_{s0} is the characteristic admittance[4] of the slot and l is the slot length.

When the voltage between the electrodes 2 and 1, 3 in a body is applied, the current distributed factor α is given by the current on the conductor 1. A numerical calculus is shown as follows:

$$y_{\text{in}} = \frac{Y_{\text{in}}}{Y_s + Y}, \qquad y_{\text{in}0} = \frac{Y_{\text{in}0}}{Y + Y_s}.$$

Setting

$$Y_1 = Y_0[1 + k(\alpha + \tfrac{1}{2})], \qquad Y_2 = Y_0[1 - k(\alpha - \tfrac{1}{2})].$$

From the above relations, the numerical results are shown in Figs. 3, 4, and 5.

Split Coaxial Type Duplexer with Outer Conductor

For the purpose of making a branch from the coaxial line A to the other coaxial lines B and C, the split coaxial-type duplexer will

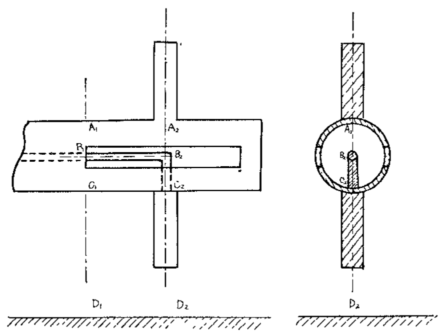

Fig. 1—Split coaxial type balun.

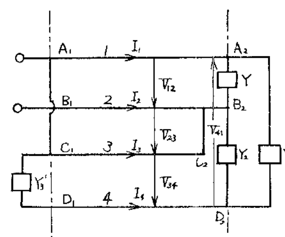

Fig. 2—Equivalent circuit of split coaxial type balun.

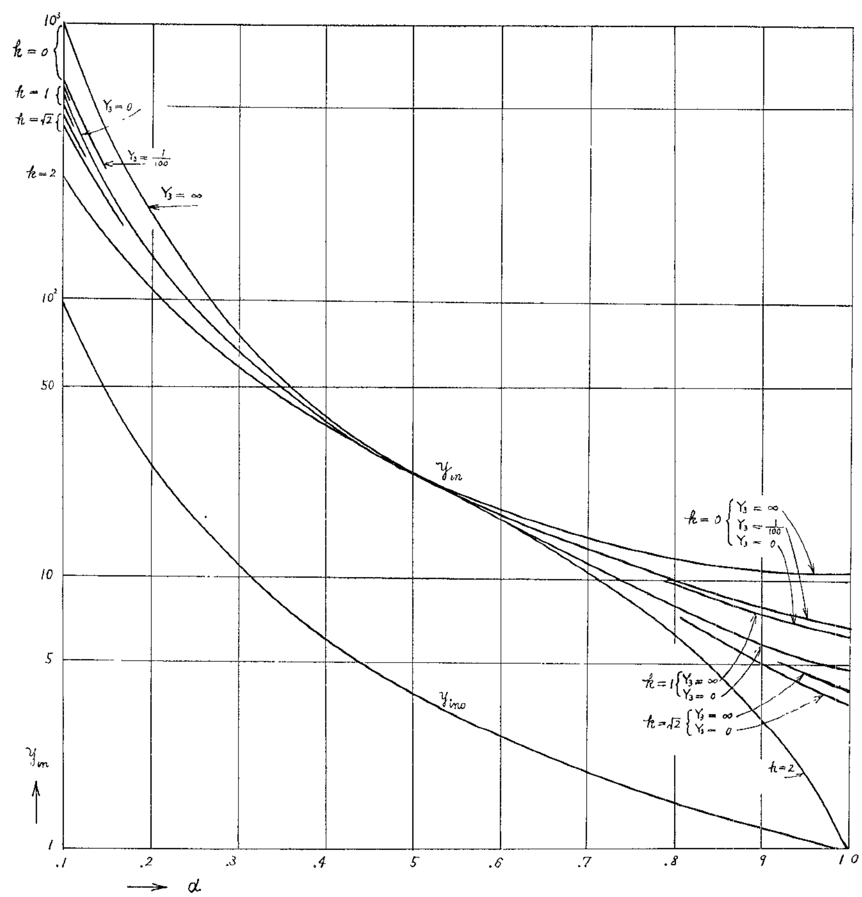

Fig. 3—Relationship between input admittance Y_{in} and current distributed factor α for $Y_0 = 1/10$ v, $Y + Y_s = 1/100$ ℧.

* Received by the PGMTT, February 13, 1959; revised September 22, 1959.

[1] H. Uchida, "Split coaxial balance converter for VHF and UHF," *J.I.E.C. of Japan*, vol. 33, pp. 406–408; August, 1951.

[2] P. A. T. Bevan, "The 100-kw ERP Sutton coldfield television broadcasting station," Proc. IRE, vol. 41, pp. 196–203; February, 1953.

[3] H. Kogō and K. Morita, "Antenna impedance transformation by means of split coaxial cylinder-type balun," *J.I.E.C. of Japan*, vol. 38, pp. 359–365; May, 1955.

[4] H. Kogō and K. Morita, "Electrode capacity of split-coaxial cylinder," *J.I.E.C. of Japan*, vol. 38, pp. 548–552; July, 1955.

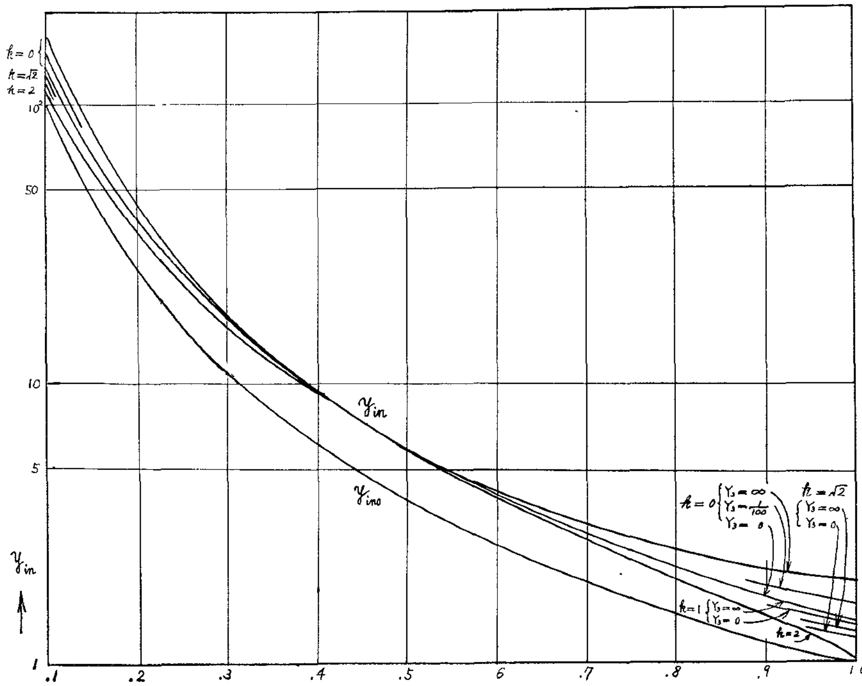

Fig. 4—Relationship between imput admittance Y_{in} and current distributed factor α for $Y_0=1/100$ ℧, $Y+Y_s=1/100$ ℧.

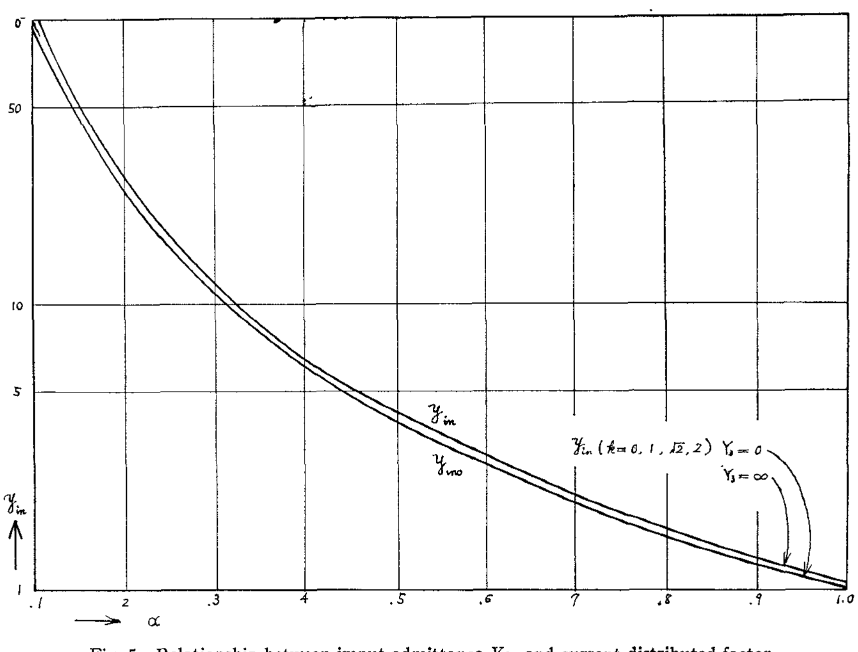

Fig. 5—Relationship between imput admittance Y_{in} and current distributed factor α for $Y_0=1/1000$ v, $Y+Y_s=1/100$ ℧.

be used frequently with the outer conductor as shown in Fig. 6. We shall now consider the impedance transform and the power division to the coaxial lines B and C. In Fig. 6 suppose that the unsymmetric duplexer segment 3 and 4 is split by the ratio $1:n$ and loaded with Y_{13}, Y_{14}. To simplify it, the slot width shall be made very small and the capacity of each electrode shall be proportionate to the segment area. Equivalent input admittance at the terminal from the coaxial side is as follows:

$$Y_{in}=\frac{i_1}{v1}=\left(\frac{n+1}{n}\right)^2Y_2+\frac{Y_{13}Y_3-Y_{14}Y_3/n+\frac{n+1}{n^2}Y_{14}Y_3+\left(\frac{n+1}{n}\right)^2Y_{13}Y_{14}}{Y_{13}+Y_{14}+Y_3}.$$

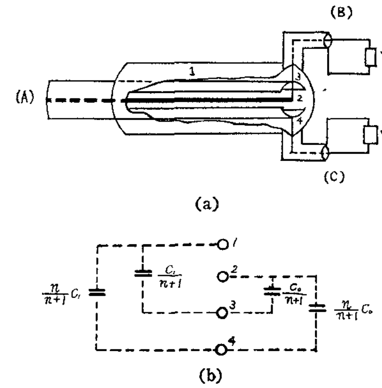

Fig. 6—Split type duplexer with outer conductor; (a) construction, and (b) electrode capacity.

Next, we will consider the power distributed to Y_{13}, Y_{14} and the equivalent input admittance as follows:

1) In the case when $Y_{13}=Y_{14}$:

$$V_{13}=-\frac{Y_{13}\left(\frac{n+1}{n}\right)+Y_3}{2Y_{13}+Y_3}v_1,$$

$$V_{14}=\frac{Y_{13}\left(\frac{n+1}{n}\right)+Y_3/n}{2Y_{13}+Y_3}v_1;$$

the power distributed to each branch is not equal. Equivalent input admittance is as follows:

$$Y_{in}=\left(\frac{n+1}{n}\right)^2Y_2+\frac{Y_{13}\left[\left(1+\frac{1}{n^2}\right)Y_3+\left(\frac{n+1}{n}\right)^2Y_{13}\right]}{2Y_{13}+Y_3}$$

where $Y_3=-i_3/v_3=jY_{1-234}\cot\beta l$, and Y_3 is the input admittance at the terminal between 1 and 2, 3, 4 in a body, and $Y_{1-2,3,4}$ is the characteristic admittance.

If $Y=0$, then,

$$Y_{in}=\left(\frac{n+1}{n}\right)^2\left(Y_2+\frac{Y_{13}}{2}\right).$$

2) In the case when $Y_{13}\neq Y_{14}$, $Y_3=0$:

$$\frac{V_{13}}{V_{14}}=\frac{Y_{14}}{Y_{13}},\quad Z_{in}=\left(\frac{n}{n+1}\right)^2(Z_{13}+Z_{14})\cap Z_2,$$

the voltage division to the ratio of the load impedance.

3) In the case when $Y_{14}/n=Y_{13}$:

$$\frac{V_{13}}{V_{14}}=n,\quad Y_{in}=\left(\frac{n+1}{n}\right)^2Y_2+\left(\frac{n+1}{n}\right)Y_{13},$$

input admittance is derived independently from Y_3.

4) In the case when $n=1$:

$$Y_{in}=2\left[\frac{(Y_{14}+Y_{3/2})(Y_{13}-Y_{14})}{Y_{13}+Y_{14}+Y_3}+(Y_{14}+2Y_2)\right].$$

When the load is symmetrical, $Y_{13}=Y_{14}=2Y$, $Y_{in}=2Y_{14}+4Y_2=4(Y+Y_2)$.

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