A–7–4 IMPROVEMENT OF SMALL LOOP ANTENNA EFFICIENCY BY USING ADJACENT DIPOLE ELEMENT

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Improvement of radiation efficiency of an electrically small loop antenna (ESLA) by an array arrangement with a parasitic dipole antenna is described. As is well known, an ESLA suffers from low efficiency mostly due to low radiation resistance and loss exsisting in the matching circuit. Hence it is evident that the reduction of the matching loss is an effective way of improving efficiency of the ESLA. An antenna system, an ESLA coupled with a dipole element, shown in Fig. 1(a) is taken as the one solution to this sort of problem. Mutual coupling between the loop and the dipole element serves as an impedance transformer to increase the input impedance of the loop antenna and therby matching is made efficiently.

The analysis and design of the antenna system will be presented and a practical example with the experimental result is also introduced. The input impedance Z_{in} seen at the terminals 1-1' of the antenna system shown in Fig. 1(a) is given by using a two-terminal expression as follows[1];

$$Z_{in} = Z_{11} - Z_{12}Z_{21}/Z_{22} = Z_{11} + Z_M, \tag{1}$$

where

$$Z_M = -Z_{12}Z_{21}/Z_{22}.$$

Dimensions of the antenna are given in Fig. 1(a). When an impedance Z_L is loaded at the midpoint of the dipole element as shown in Fig. 1(b), $(Z_L + Z_{22})$ replaces Z_{22} in Eq.(1).

The numerical calculation of the impedance is performed by the moment method which was arranged by Chao[2], where Galerkin's method with triangle piece wise current expansion functions was used. As can be expected, Z_{in} may be changed by the factor of Z_M, which is essentially determined by the mutual coupling between the loop and the dipole, that can be changed depending upon the length h of the dipole and the distance d of the two elements. Since Z_{11} is almost reactive when the loop is very small, Z_M, thus $Z_{12}=Z_{21}$ acts as a very important role to increase Z_{in}. Variation of $Z_{12}(=R_{12}+jX_{12})$ with the loop diameter b is shown in Fig.2, where R_{12} is not shown because of being negligible small value. $Z_{22}(=R_{22}+jX_{22})$ and Z_{12} are shown for the dipole length h in Fig.3. It can be predicted that if X_{22} is made zero (the dipole is resonant) and R_{12} is neglected, Z_M becomes $-(-jX_{12})^2/R_{22}$, which is real value, and then Z_{in} will be $(jX_{11} + X_{12}^2/R_{22})$, that can be a real value appropreate for matching, with X_{11} being compensated by a conjugate impedance.

An example is shown by an antenna, dimensions of which are b=0.032λ, h=0.5λ, and d=0.0016λ. Although R_{11} of this antenna is only 0.5Ω, by means of dipole coupling Z_{in} is increased to be 52.5Ω in real, with the reactive component of Z_{in} being compensated by a capacitance.

The frequency dependence of the input impedance Z_{in} of this antenna is shown in Fig.4, where the antenna is tuned to the center frequency by a capacitance placed at the input terminals 1-1'. As the VSWR is less than 2 over the frequency range of 10 percents, the frequency performance may be said to be fairly good, although the size of the loop is very small.

When the dipole length is shortened, loading technique is considered useful. As the dipole length h is shortened, R_{22} becomes small and X_{22} tends to be negative value. It can be seen from Fig.3, that the variation of X_{12} is not so rapid as that of X_{22}. By using this fact, similar arrangement for Z_{in} as the previous example can be applied, and with aid of the impedance loading, Z_{in} can be adjusted to be a real value. For example, by using a λ/4 dipole, to which an inductance of 480Ω is loaded, approximately 300Ω is attained for Z_{in}, which is shown in Fig. 5.

A practical example using a ferrite-antenna coupled with a dipole element is shown in Fig.6, where the increase in the output of the ferrite antenna is shown as the distance, thus coupling, varies.

In practice, a dipole element for the coupling purpose may be substituted by any dipole-like materials; a microphone code, a wire attached to a human body, or sometimes human body itself may substentially act as a dipole element to realize the conditions discussed above.

In various small size communication equipment in HF and VHF bands equipped with a built-in type antenna, such as a loop, and a ferrite-loop, space available for it is usually very limited, so that the gain is actually forced to be lowered by the effect of adjacent materials, in addition to the low efficiency due to the smallness of the antenna. For these situations, utilizing these materials as dipole element or placing a dipole-like element intentionally to couple with the built-in loop antenna may be very effective to obtain the improvement in the efficiency of the ESLA. So far the dipole-coupled ESLA system has been applied to various practical equipment and its usefulness has been evidenced by most of their applications.

REFERENCES

(1) R.H.Harrington: Field Computations by Moment Method, p.111, MacMillan Company (1968).

(2) Hu H.Chao, and B.J.Strait: Computer Programs for Radiation and Scattering by Arbitrary Configulations of Bent Wires, Scientific Report No.7, Syracuse University (1970).

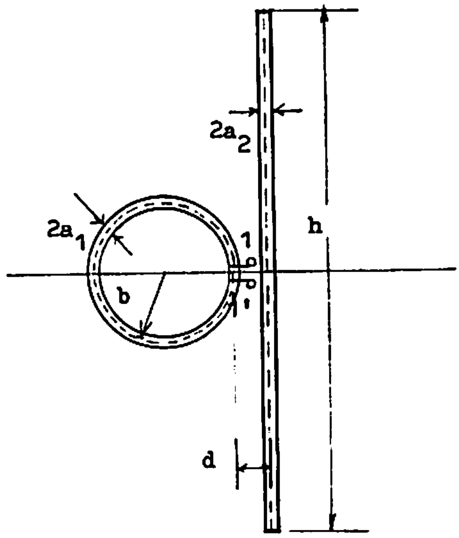

Fig.1(a)
Geometry of the ESLA-dipole System.

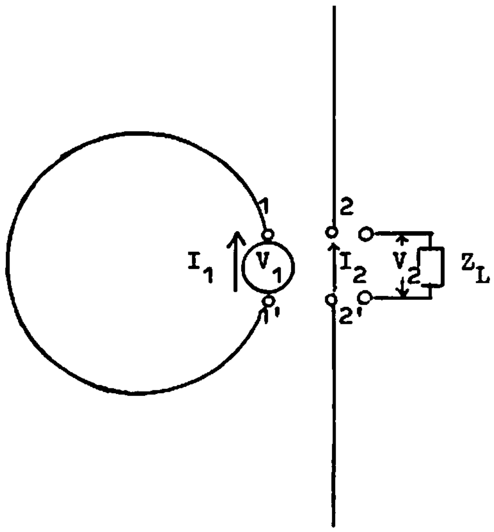

Fig. 1(b)
Representation of the antenna System.

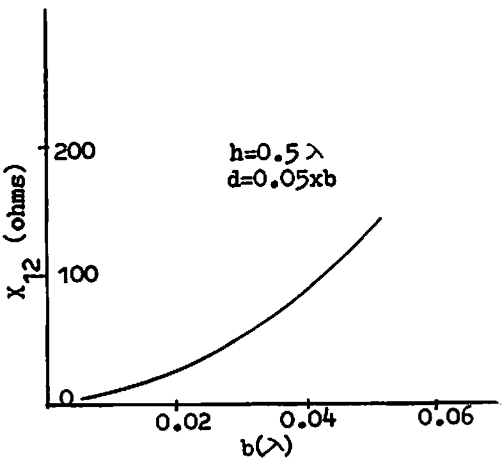

Fig.2 X_{12} vs. b

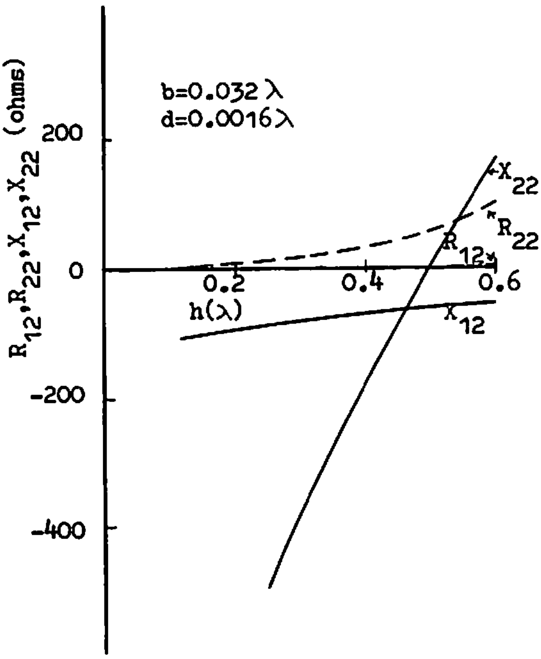

Fig.3 Z_{12} and Z_{22} vs. h

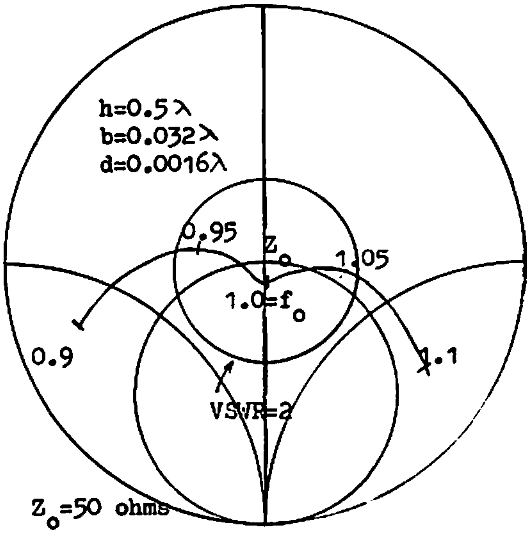

Fig. 4
Frequency Dependence of Z_{in}

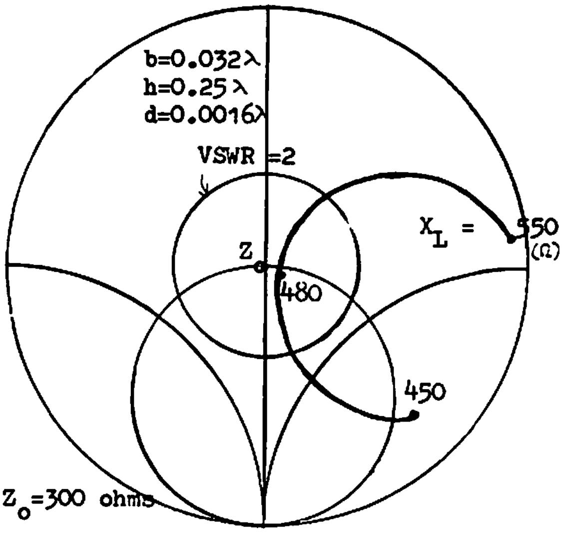

Fig.5
Variation of Z_{in} with Loading Impedance.

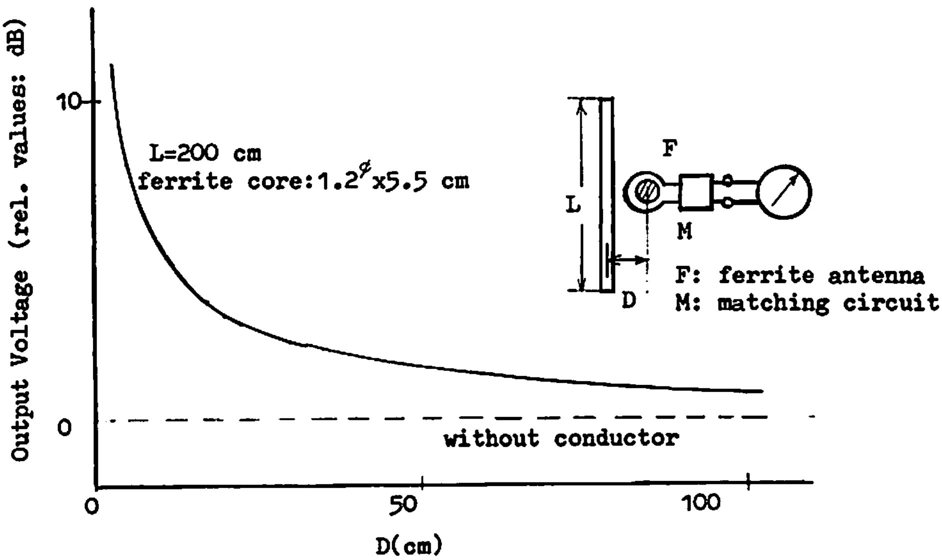

Fig. 6
Output Voltage of Ferrite-Loop Antenna vs. D.