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MODIFIED TWO PLANES SELF-COMPLEMENTARY ANTENNA

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It is well known that the impedance of a three dimensional self-complementary antenna composed of n number of planes is $60\pi/n$ ohms [1,2]. For a two port self-complementary antenna, if one port is loaded by a $60\pi/n$ ohms resister, the impedance looked from the other port is also $60\pi/n$ ohms. However, the radiation pattern consists of several main beams that reduce the antenna gain. The occurence of these multiple main beams is attributed to the finite sizes of the antenna planes and the symmetrical geometry of the structure. Therefore, aiming at an improved gain, a modification of the symmetrical characteristics of the antenna system is desired so that the number of these main beams can be controlled. In this paper, we shall discribe a two-plane self-complementary structure which after modification has a singlemain beam with a shift of the impedance.

Fig. 1 shows the co-ordinate system of the antenna structure under consideration. The input and output ports are noted as a, b and c, d respectively. The slot and the unipole are of lengths 2ℓ and ℓ respectively and of equal width w. The modification is such the dotted unipole is taken off from the original self-complementary structure. Regarding the modified structure, if the width of the unipole or the slot is sufficiently small compared with its length as well as a wavelength, the field analysis of the antenna structure can be performed by the decomposition shown in Fig. 2. The analysis shows that if the load impedance is $Z_o/(2\sqrt{2})$ ohms, ($Z_o=120\pi$), the input impedance is also $Z_o/(2\sqrt{2})$ which is frequency independent. Mayes et. al.[3] have studied the similar antenna and used other equivalent circuit which leads to different results. With a sinusoidal current distribution, the radiation field of the proposed antenna can be obtained from the equation,

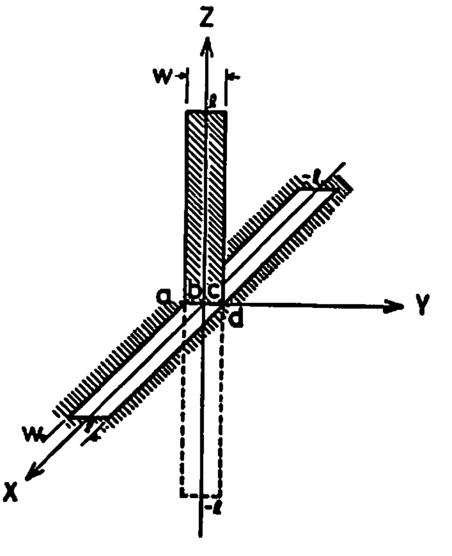

Fig.1 The structure of the antenna under consideration and co-ordinate system.

$$\mathbf{E} = j60e^{-jkr}\frac{I_u}{r\sin k\ell}\cdot\Big\{2\cdot\frac{\cos(k\ell\cos\theta)-\cos k\ell}{\sin\theta}\hat{e}_\theta - \sqrt{2}\,\frac{\cos(k\ell\sin\theta\cos\phi)-\cos k\ell}{1-\sin^2\theta\cos^2\phi}\cdot\left(\sin\phi\,\hat{e}_\theta+\cos\theta\cos\phi\,\hat{e}_\phi\right)\Big\},\quad 0<\theta<\frac{\pi}{2},$$

$$\mathbf{E} = j60e^{-jkr}\frac{I_u}{r\sin kl}\cdot\sqrt{2}\cdot\frac{\cos(kl\sin\theta\cos\phi)-\cos kl}{1-\sin^2\theta\cos^2\phi}\cdot(\sin\phi\,\hat{e}_\theta+\cos\theta\cos\phi\,\hat{e}_\phi),\quad \frac{\pi}{2}<\theta<\pi .$$

The finite extent of the antenna planes is expected to modify the radiation patterns considerably. However, a single main beam has been observed instead of two main beams occurring in the original structure.

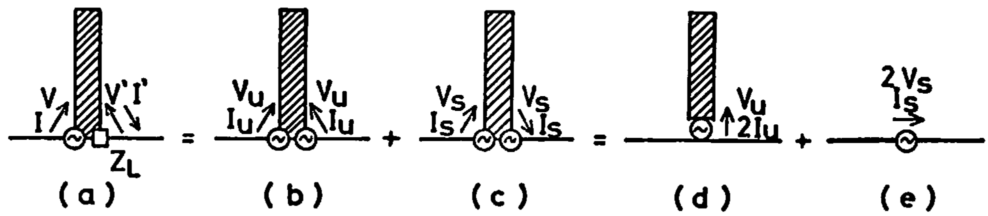

Fig.2 Decomposition of the modified self-complementary antenna and its equivalent transformation.

In order to verify the theoretical results, the impedance and the patterns have been measured with a unipole (3.75cm x 0.375cm) and a slot (7.5cm x 0.375cm) on a rectangular sheet, 36cm x 30cm as given in Fig.3 and 4. The measured impedance of the modified and the original structures are shown in Fig.3 and 4 respectively. The measured impedances are represented as 50-Ω system on Smith charts. These results confirm the predicted impedances of the modified and original structures as $30\sqrt{2}\pi$ and 30π respectively. The measured radiation patterns are shown in Fig.5. The occurrence of a single main beam predicted theoretically for the modified structure has been experimentally observed. It is interesting to check the frequency independence of the modified model with no restrictions on the shapes of the unipole and the slot. Fig.6 shows a modified self-complementary antenna composed of a triangular slot. The measured impedance of this structure is shown in Fig.7. As was expected, the impedance is $30\sqrt{2}\pi$ ohms and frequency independent. Thus the frequency independence of modified model is retained irrespective of the shapes of the unipole and the slot.

Next, in order to obtain a broad band and high gain characteristics, we considered an equally spaced and tapered array as given in Fig.8 [4]. It is considered that the frequency independent characteristics can be obtained above a frequency determined by the length of the longest element. The length of the longest element is taken as a quarter wavelength of the useable lowest frequency. The measured impedance of this antenna structure is shown in Fig.9. The values meet around $30\sqrt{2}\pi$ ohms as was expected. The measured radiation pattern has been found to be unchanged for frequency variation and is illustrated by a typical pattern shown in Fig.10. Fig.11 shows the received power measured at the main beam direction for a frequency variation of 0.95 to 1.9 GHz in comparison with that of a log-periodic antenna having a gain of about 8 dBi. The cross polarization component measured at the same direction is less than -20 dB. As a result, it can be found that the gain of this trial antenna is around 10 dBi for frequencies above 0.95 GHz taking account of matching loss at the feeder.

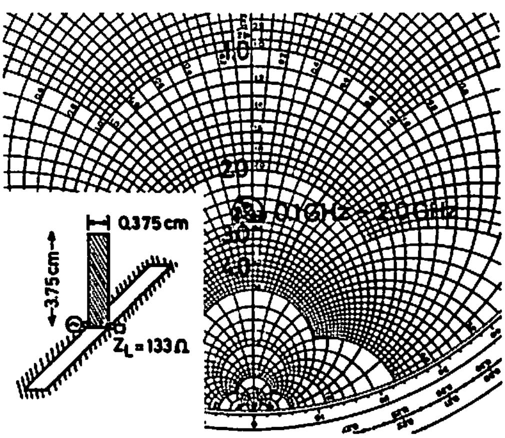

Fig.3 The measured impedance of the modified structure.

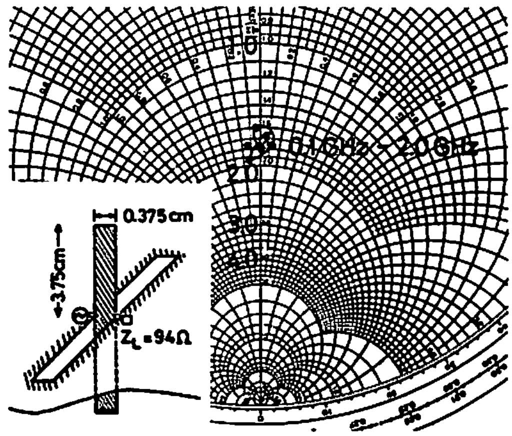

Fig.4 The measured impedance of the original structure.

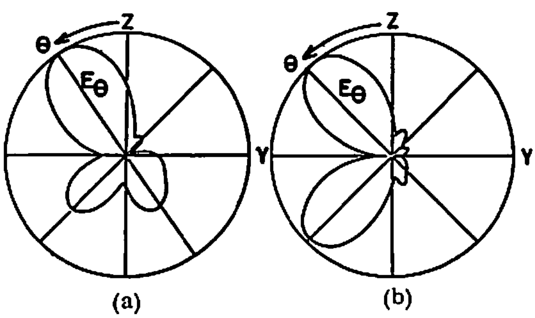

Fig.5 Measured field patterns in YZ-plane, f=1.6GHz. (a) modified structure. (b) original structure.

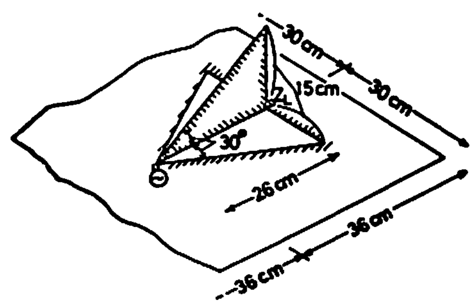

Fig.6 The modified self-complementary antenna composed of a triangular slot.

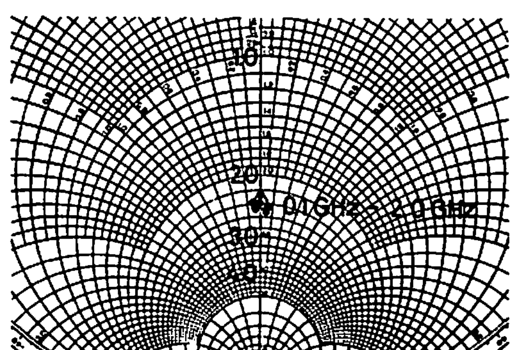

Fig.7 The measured impedance of the antenna given in Fig.6.

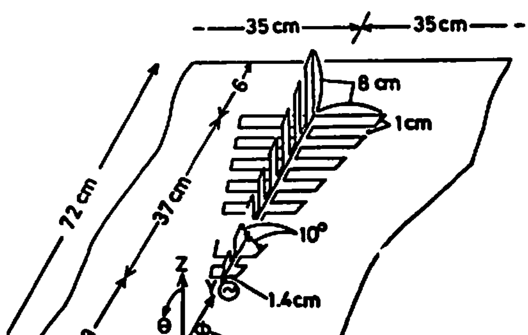

Fig.8 The structure of the equally spaced and tapered array.

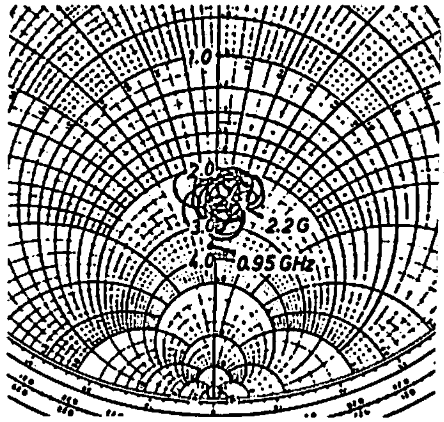

Fig.9 The measured impedance of the equally spaced and tapered array.

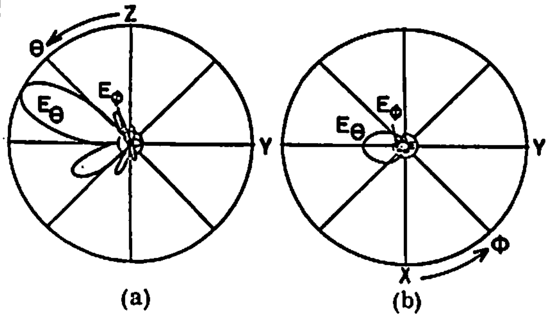

Fig.10 The measured field patterns of the equally spaced and tapered array, f=1.4GHz. (a) YZ-plane. (b) XY-plane.

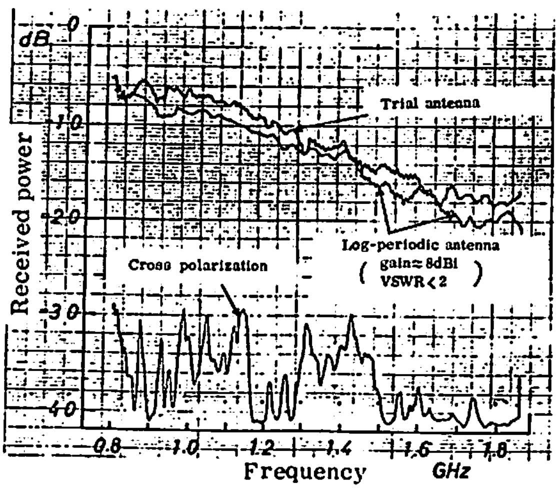

Fig.11 Received power for various frequency.

Thus, it is found that although a modification is made as stated above on the unipole or the slot of a self-complementary structure, the impedance is shifted but the frequency independent properties are retained. Broad band and high gain characteristics of the antenna can be achieved from equally spaced and tapered array constructed under the proposed modification.

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References

1. Y. Mushiake and H. Saito, "On three dimensional self-complementary antennas" Joint Conference of Electrical Engineering of Japan, p.1212, 1963.
2. Yasuto Mushiake, "Constant impedance antennas" IECE of Japan, Vol.48, No.4, pp.580-584, April 1965.
3. Paul E. Mayes, W. T. Warren and F. M. Wiesenmeyer, "The monopole slot : A small broad-band unidirectional antenna" IEEE Trans. Antennas Propagat., Vol.AP-20, No.4, pp.489-493, July 1972.
4. T. Kasahara and Y. Mushiake, "Three dimensional self-complementary antenna composed of equally spaced array of unbalance type" National Convention Record of IECE of Japan, p.594, 1978.