# A-4-3 MICROSTRIP LINE ARRAY ANTENNA AND ITS APPLICATION

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## Introduction

In this paper we have proposed Microstrip Line Array Antenna (hereafter refered to as MSAA). As shown in Fig.1, it consists of a group of series slots which are positioned on the ground plane along a microstrip line. There are two basic types of MSAA; the resonant array when the transmission line is terminated in an open-circuit at a distance L beyond the last slot and the nonresonant array when terminated in a matched load. The resonant array is designed for broadside operation, while the nonresonant array can be designed to have the main lobe at any angle except the broadside direction. We describe the design procedure, the radiation pattern and the gain of the resonant array. Also we have succeeded in building a 16 by 20 MSAA of which the gain is about 28 dB at $12GH_z$ band, based on this design procedure with a uniform aperture distribution. This array is applicable to the antenna for the broadcasting satellite direct reception.

## Design procedure

The equivalent circuit of MSAA for the resonant array is shown in Fig.2. To obtain broadside radiation all the slots must be excited in phase. This can be achieved by spacing the slots one guide wavelength $\lambda_g$ apart. At the same time L should be choosed to be in the vicinity of $\lambda_g/4$.

The slots are assumed to be resonant at a design frequency. The power $P_{rn}$ radiated from the $n$th element is proportional to the real part of the slot impedance. We shall now consider the problem of specifying the slot resistances $r_n$ for the resonant array. We shall let $A_n$ be the desired excitation ratio of $P_{rN}$ by the $N$th element and $P_{rn}$ by the $n$th element and let $\gamma=\alpha+j\beta$ be the complex propagation constant for the microstrip line. The following equations are then given, using the notation in Fig.2.

$$r_n = A_n r_N \frac{|1-\Gamma_N|^2}{|1-\Gamma_n|^2} \frac{1}{\prod_{i=n+1}^{N} |[1+(1-\Gamma_i)\frac{r_i}{2}]\exp(\gamma l_{i-1})|^2} \quad , (n=1,2,---,N-1) \qquad (1)$$

$$\Gamma_N=\exp(-2\gamma L)$$

$$\Gamma_{n-1}=\frac{r_n/2 +(1-r_n/2)\Gamma_n}{1+r_n/2 -(r_n/2)\Gamma_n}\exp(-2\gamma l_{n-1}) \quad , (n=1,2,---,N) \qquad (2)$$

$\Gamma_0$ expresses a reflection coefficient on the input and $l_0=0$ for n=1.

The design procedure based on the above equations proceeds as follows: 1. Let L be $\lambda_g/4$. Determine the ratio $A_n$ in order to achieve the desired aperture distribution. 2. Substituting an initial value for $r_N$, $r_n$ is successively computed through the use of (1), (2) and $|\Gamma_0|$ can be calculated. 3. In order for the array to be matched to the characteristic impedance $Z_0$, the steps in 2. are repeated till $|\Gamma_0|$ converge to the designated value, for example, as 0.001.

The resonant resistance $R_d$ of the slot in the microstrip line at an arbitrary offset position can be evaluated from the following equations when $f(x)=|x|$ is assumed for the current distribution on microstrip conductors.

$$R_d=\frac{\left[\int_{-a/2-d}^{a/2-d}\left\{\frac{1}{2\pi}\int_{-\infty}^{\infty} g(\zeta)\,\frac{\exp(-j\zeta x)}{\exp(|\zeta h|)}\,d\zeta\right\}\cos\frac{\pi}{a}(x+d)\,dx\right]^2}{\frac{8}{3\pi}\sqrt{\varepsilon_0/\mu_0}\,\left(\frac{a}{\lambda_0}\right)^2\left[1-0.374\left(\frac{a}{\lambda_0}\right)^2+0.13\left(\frac{a}{\lambda_0}\right)^4\right]} \tag{3}$$

$$g(\zeta)=\frac{\sin\left(\frac{\zeta w}{2}\right)}{\frac{\zeta w}{2}}-\frac{1}{2}\,\frac{\sin^2\left(\frac{\zeta w}{4}\right)}{\left(\frac{\zeta w}{4}\right)^2}$$

$\lambda_0$: wavelength in free space

A few examples calculated by (3) are shown in Fig.3. Therefore the slot offset $d_n$ may be found once $r_n$ has been specified.

## Experiments and discussion

On the basis of the above design procedure we have fabricated the completed 320-slot array with a uniform aperture distribution to operate at $12GH_z$, using copper-clad Fiberglas laminate whose relative dielectric constant is about 2.5 and which is $h$=0.073cm thick. In the design and the calculation the 9 dB/m (measured value) has been used for the microstrip line attenuation and 0.667 for the $\lambda_g/\lambda_0$.

Fig.4 is a photograph of this antenna with reflector removed. Reflector has been attached about $\lambda_0/4$ ($\lambda_0$: wavelength at $12GH_z$) apart from the surface of dielectric substrates. Antenna patterns taken in the E and H planes are shown in Fig.5. The measured values at $12GH_z$ are shown in Table 1. Also the measured gains at 11.8 and $12.2GH_z$ is 28.5 and 28.6 dB, respectively. On the other hand the calculated gain at $12GH_z$ is about 28.6 dB. It should be noted that the gain in the broadside direction deteriorates with a change in frequency away from the design frequency because of a beam tilt of a main lobe.

## Conclusion

The design procedure and the characteristics of MSAA which has been proposed to use reproducible printed circuit technology are elucidated, and the completed 320-slot array has been built. The performance of the array almost agrees with the prediction.

## Acknowledgment

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## References

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[2] M.Collier,"Microstrip antenna array for $12GH_z$ TV," Microwave Journal, Sept. 1977, p.67.

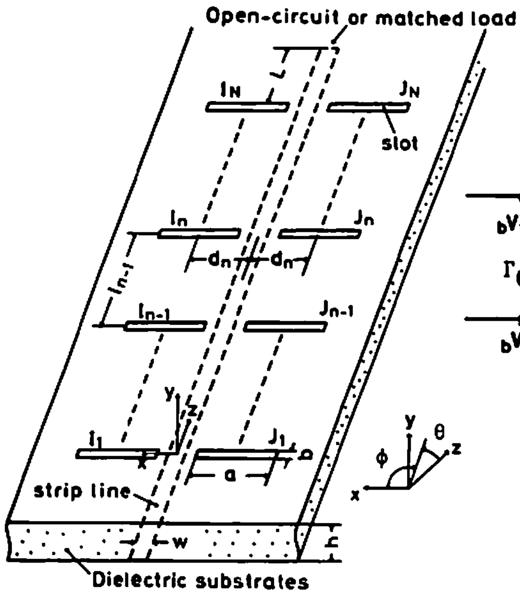


Fig. 1. Typical microstrip line array antenna.

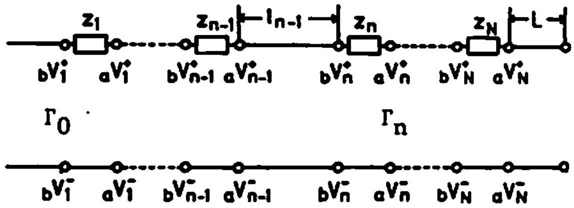

Fig. 2. Equivalent circuit of MSAA for resonant array.

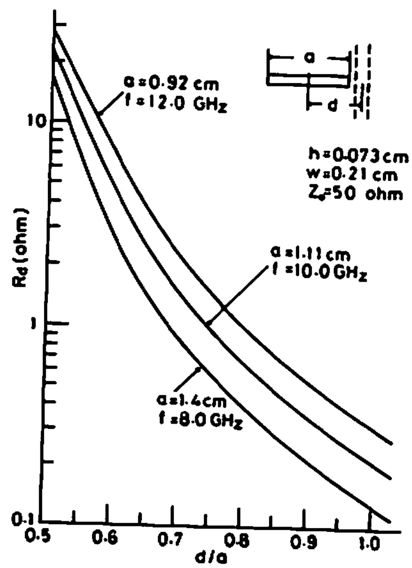


Fig. 3. Calculated curves of resonant resistance $R_d$ of slot in microstrip line as a function of relative displacement $d/a$.

Table 1 Measured values of completed 320-slot array with reflector at 12 GHz

| Characteristics | | Measured values |
|---|---|---|
| Gain | | 27.6 dB |
| Beamwidth | E plane | 4.8° |
| | H plane | 3.8° |
| Sidelobe level | | |
| | E plane | -12 dB Max |
| | H plane | -10 dB Max |
| VSWR | | 2.2 : 1 |
| F/B ratio | E plane | -38 dB |
| | H plane | -37 dB |

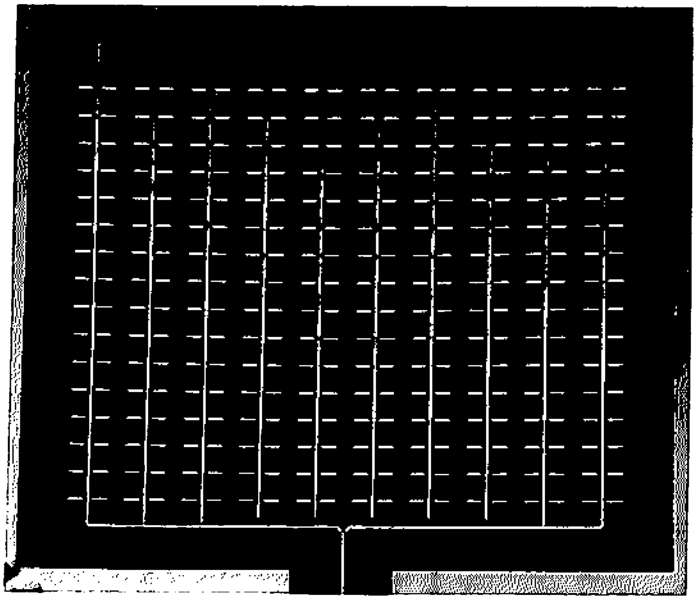

Fig. 4. Completed 320-slot array with reflector removed.

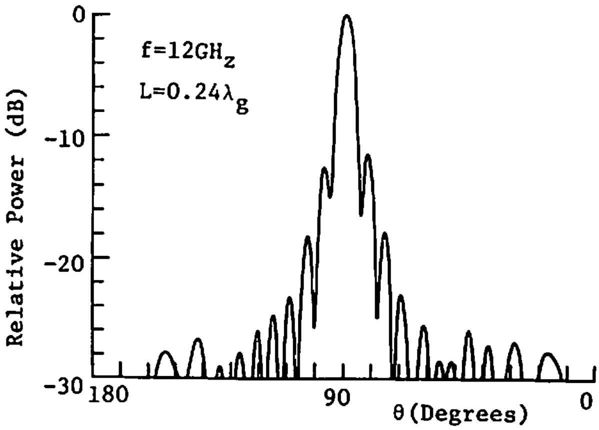


Fig. 5(a). Measured E-plane pattern.

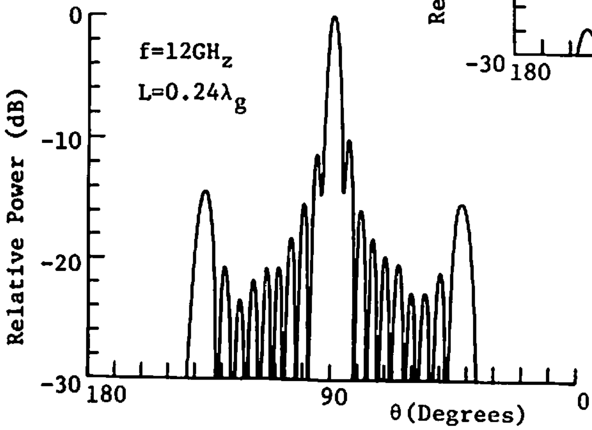


Fig. 5(b). Measured H-plane pattern.