COMPUTER AIDED DESIGN OF A WIDEBAND COPLANAR MICROSTRIP SUBARRAY

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ABSTRACT:

This paper presents a Computer Aided Design solution for a coplanar microstrip cross-shaped subarray with parasitic elements. An impedance bandwidth up to 18% is obtained for a subarray with seven elements. Each Subarray is based on rectangular patches etched on a grounded substrate. The active patch is fed by a coaxial probe. Numerical results for both the return loss and radiation pattern for several subarrays are presented and discussed.

I. INTRODUCTION:

One way to increase the bandwidth of a microstrip patch antenna is to introduce closely spaced parasitic patches on the same layer with a fed (active) patch. Wood [1] has shown that the impedance bandwidth can be improved using adjacent patchs. A coplanar microstrip parasitic subarray may be formed by a special class of configurations consists of one fed patch and two or more parasitic patches placed symmetrically around the active patch. This class of configurations is of considerable interest and was studied theoretically and experimentally. Gupta [2] showed that the impedance bandwidth can be improved by using parasitic patches smaller than the active patch. Many investigators have used parasitic patches with the same size as the active patch and improved gain characteristics [3]-[5]. Planar array of a cross-shaped five-patch subarray were build and tested by Miller et al [6]. Chen et al [7] have presented the results for radiating -edge- coupled three- and 5-element subarray in which the parasitic patches are of the same size as the active patch. The impedance bandwidth obtained was about 5-6 %.

In this paper, we investigate improvement of the input impedance bandwidth for the cross-shaped subarray configuration using microstrip technology. Cases considered include 5- and 7-element subarrays. Numerical results are computed using Microwave Office 2001 software distributed by Applied Wave Research, Inc.

II. BASIC FORMULATIONS:

Electromagnetic (EM) simulators use Maxwell's equations to compute the response of a structure from its physical geometry. EM simulations are ideal because they can simulate highly arbitrary structures and still provide very accurate results. In addition, EM simulators are not subject to many of the constraints of circuit models because they use fundamental equations to compute the response. One limitation of EM simulators is that simulation time grows exponentially with the size of the problem, thus it is important to minimize problem complexity to get timely results.

Microwave Office's EM simulator, known as EMSight, is capable of simulating planar 3D structures containing multiple metallization and dielectric layers. The structures can have interconnecting vias between layers or to ground. EMSight uses the Galerkin Method of Moments (MoM) in the spectral domain, an extremely accurate method for analyzing microstrip, stripline, and coplanar structures as well as other more arbitrary media. Properly used, this technique can provide accurate simulation results up to 100 GHz and beyond.

For an simple region as in fig.1 the current in radiating elements and feeding elements is expanded into a set of basis functions : $\vec{J} \approx \sum_{j=1}^{N} C_j J_j$, (1)

where J_j are the basis functions and C_j corresponding coefficients.

In case that the simple region is connect to the outside through aperture coupling, the field in apertures is expanded into basis functions : $\vec{E} \approx \sum_{k=1}^{M} \gamma_k \vec{E}_k$ (2)

Thus, the magnetic current excitation over the apertures is expressed by :

$$\vec{M}_a \approx \sum \gamma_k \vec{M}_k \text{,where: } \begin{array}{l} \vec{M}_a = \vec{E}_a x \vec{n} \\ \vec{M}_k = \vec{E}_k x \vec{n} \end{array} \qquad (3)$$

If all metal sheets are perfect conducts, tangential electric field will vanish on all metallic surfaces inside the region, so:

$$\vec{E}(\vec{J}) + \vec{E}(\vec{M}_a) = 0 \qquad (4)$$

If the metal sheets are not perfect conducts, we have to apply the impedance boundary conditions:

$$\vec{E}(\vec{J})+\vec{E}(\vec{M}_a)=Z_s\vec{J} \qquad (5)$$

Z_s is the impedance surface(Ω / square meter).

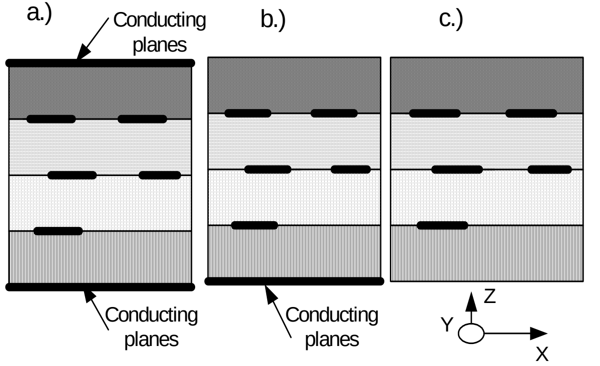


Fig. 1 Simple region. Conducting patches embedded in multiplayer dielectric media bounded by a.) two conducting plane b.) one conducting plane c.) no conducting boundaries other than the patches**.**

In specific case of rectangular microstrip antennas with a coaxial feed (Fig.2) total current on the patch and probe is expanded into:

$$\vec{J}_s=\sum_{n=1}^{N}a_n\vec{f}_{patch,n}+\sum_{m=1}^{M}C_m f_{zm}\vec{z}+d\,\vec{f}_{atta} \qquad (6)$$

$\vec{f}_{patch,n}$ - Basis function on the patch, f_{zm} - basis functions on the probe, and f_{atta} - special basis functions to ensure the continuity of current at the patch – probe junction. The field inside coaxial cable can be expressed as:

$$\vec{E}_{z\le z_g}=\vec{E}_0(\vec{r}_s)e^{-jk_0(z-z_g)}+\sum_{l=1}^{L-1}\Gamma_l\vec{E}_l(\vec{r}_s)e^{-jk_{lz}(z-z_g)} \qquad (7)$$

$$\vec{H}_{z\le z_g}=\vec{H}_0(\vec{r}_s)e^{-jk_0(z-z_g)}+\sum_{l=1}^{L-1}\Gamma_l\vec{H}_l(\vec{r}_s)e^{-jk_{lz}(z-z_g)} \qquad (8)$$

$\vec{E}_0$ *and* $\vec{H}_0$ the fields of TEM mode, $\vec{E}_l$ *and* $\vec{H}_l$ (l >0) , are the fields of higher modes.

$\vec{r}_s=x\vec{x}+y\vec{y}+z\vec{z},\ \ \vec{r}_s=x\vec{x}+y\vec{y}$, where z_g is the z-coordinate of the ground plane which we take as a reference point.

The field on aperture ($z=z_g$) is:

$$\vec{E}_a=\vec{E}_0(\vec{r}_s)+\sum_{l=1}^{L-1}\Gamma_l\vec{E}_l(\vec{r}_s)$$

(9)

$$\vec{H}_a=\vec{H}_0(\vec{r}_s)+\sum_{l=1}^{L-1}\Gamma_l\vec{H}_l(\vec{r}_s) \qquad (10)$$

If $\vec{E}_0,\ \vec{H}_0$ are the known incident field and using (4) and (5) it is possible to solve equations for the unknown coefficients.

The input impedance Z_{in} of the antenna is

$$Z_{in}=Z_0\frac{1+\Gamma_0}{1-\Gamma_0}, \qquad (11)$$

$$\Gamma_0-reflection\ \ coefficient$$

$$Z_0-Characteristic\ impedance\ of\ the\ coaxial\ cable$$

If only the TEM mode is used (while coaxial cable is smaller than the dimension of the patch), the input impedance will be (for detail see lit. [8]):

$$Y_{in}=\frac{1}{Z_{in}}=\frac{\sum_{n=1}^{N}a_n\left\langle\vec{f}_{patch,n},\vec{M}_0\right\rangle+\sum_{m=1}^{M}a_n\left\langle f_{zm}\vec{z},\vec{M}_0\right\rangle+d\left\langle\vec{f}_{atta},\vec{M}_0\right\rangle+b_0\left\langle\vec{M}_0,\vec{M}_0\right\rangle}{b_0\left\langle\vec{H}_0,\vec{M}_0\right\rangle}$$

$$,\ b_0=1+\Gamma_0$$

12)

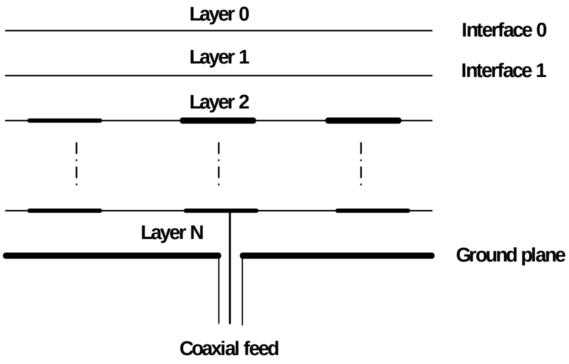


Fig. 2 Geometry of probe feed rectangular microstrip antenna in planar layered medium

III. GEOMETRY OF OUR MODEL

Geometry of a probe fed rectangular patch on a grounded substrate (side view) is the same with parasitic patches and is shown in fig.1. While the geometry of the subarray with five and seven elements are shown in fig.4, where **a, b, x, d** are geometrical parameters which are changed to find the best solution for each subarray.

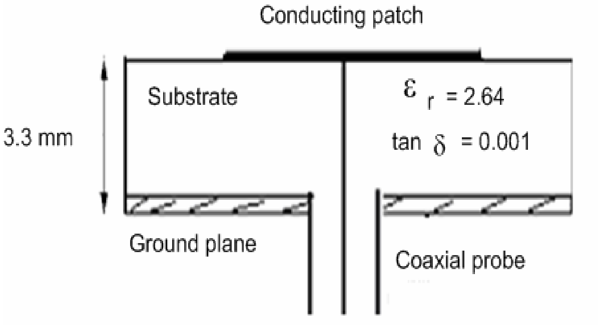
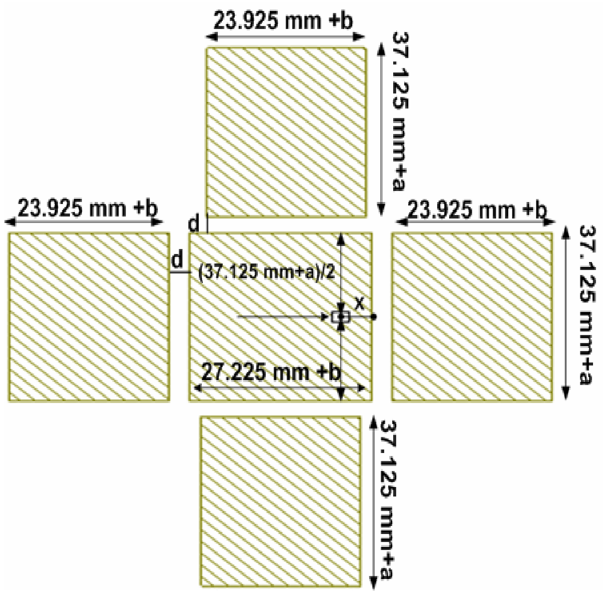
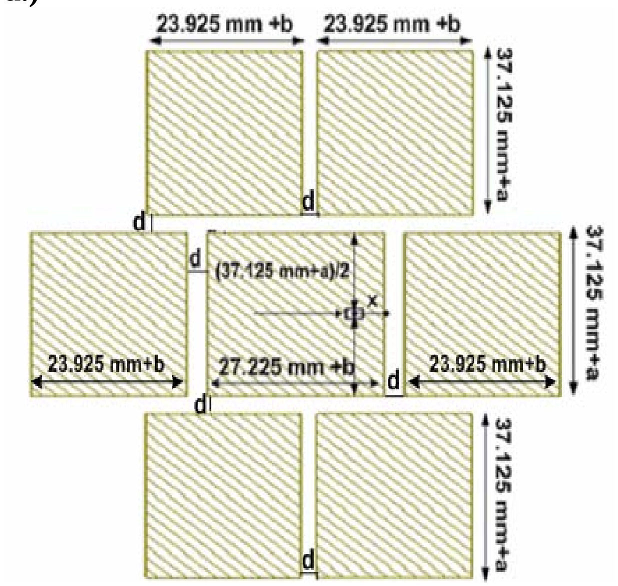


Fig. 3 Geometry of probe fed rectangular patch on a grounded substrate



a.)



b.)

Fig. 4 Geometry of coplanar microstrip cross-shaped subarray with. a) five patch b) seven patch

IV. NUMERICAL RESULTS:

a.) Coplanar microstrip cross-shaped subarray with five patch

Here we have presented results for the return loss in rectangular coordinates, by changing one geometrical parameter of the patches while others are fixed. In fig 5 a,b,c,d results for subarray with five elements are shown and in fig 6 a,b,c,d for subarray with seven elements. Fig 5a shows that feed point is very sensitive parameter for impedance bandwidth and the best results are for **x=1.65 mm**. Based on fig.5b we can see that the subarray is very sensitive gap space and the best solution for large impedance bandwidth is for **d=2.475 mm.** Fig 5c show that by changing patch length it is not possible to increase impedance bandwidth, but it is tried as an attempt to see the effect on the gain of radiating pattern. Also, by changing patch width it is possible to move with impedance resonance frequency (fig 5 d).

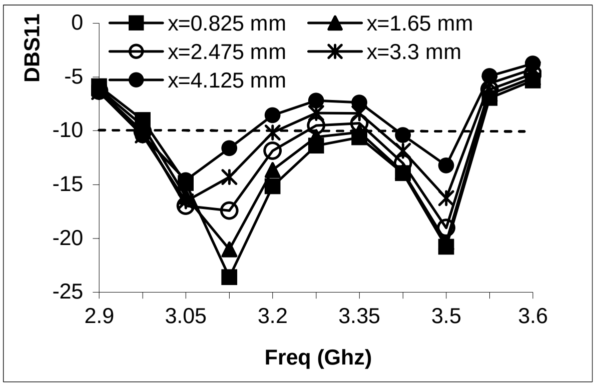


Fig 5a. Results by changing the feed point x , while other parameters are fixed: d=2.475 mm, a=0 mm, b=0 mm

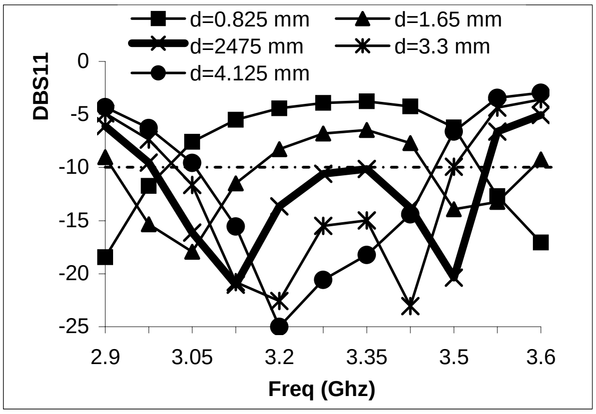


Fig. 5b. Results by changing the gap spacing (parameter d), while other parameters are fixed:x=1.65 mm, a=0 mm, b=0 mm

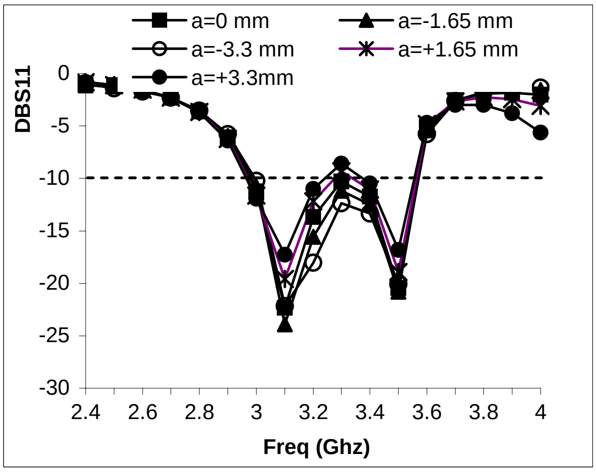


Fig. 5c. Results by changing the pach length (parameter a), while other parameters are fixed : d=2.475 mm, x=1.65 mm, b=0 mm

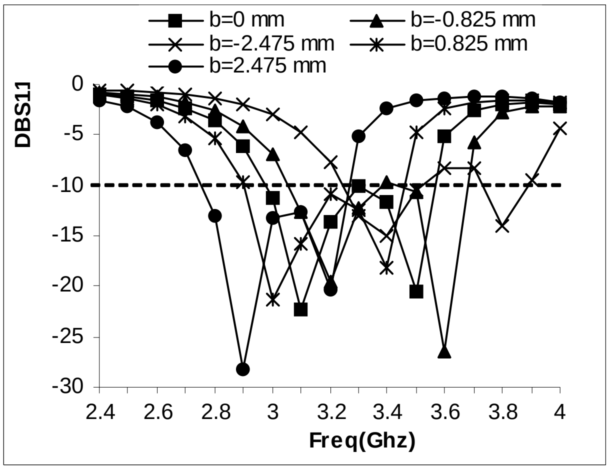


Fig.5d. Results by changing the pach width (parameter b), while other parameters are fixed: d=2.475 mm, x=1.65, a=0 mm

b.) Coplanar microstrip cross-shaped subarray with seven patch

Here we present the same parametric analysis as we have done before with five elements. Based on the next graphical presentations (fig.6 a,b,c,d) we can see that there is no significant benefit in impedance bandwidth and we can observe that the same effect while we change geometrical parameters. But , this effect here is more clear and it is easy to pick the best corresponding solution.

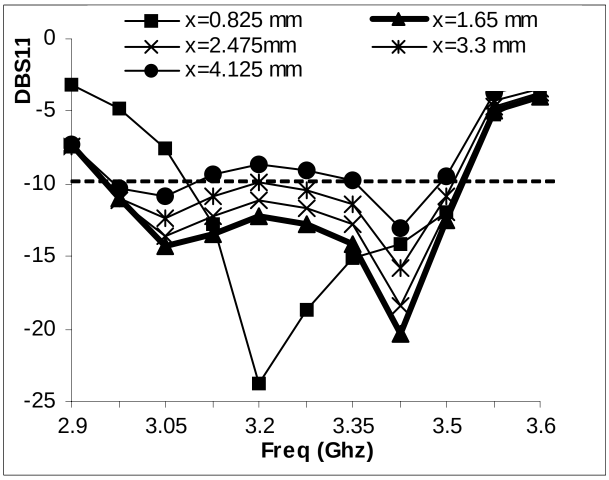


Fig 6a. Results by changing the feed point x , while other parameters are fixed: d=2.475 mm, a=0 mm, b=0 mm

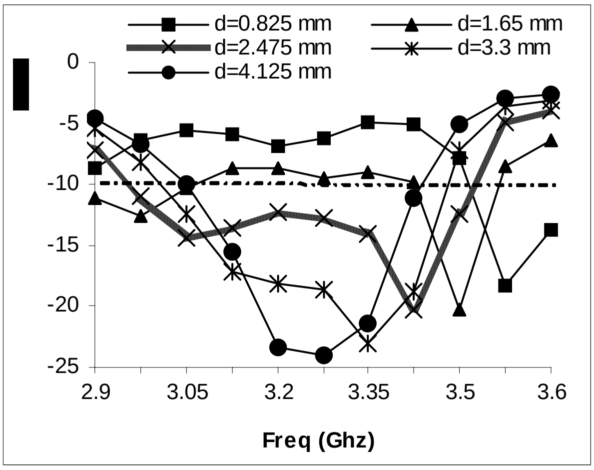


Fig. 6b. Results changing the gap spacing (parameter d), while other parameters are fixed: x=1.65 mm, a=0 mm, b=0 mm

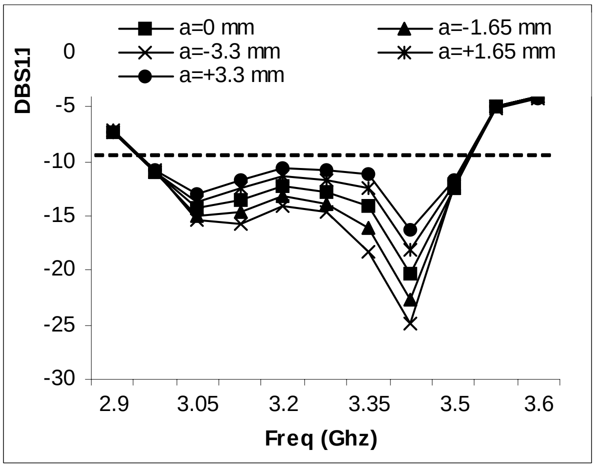


Fig. 6c. Results by changing the patch length (parameter a), while other parameters are fixed, d=2.475 mm, x=1.65 mm, b=0 mm

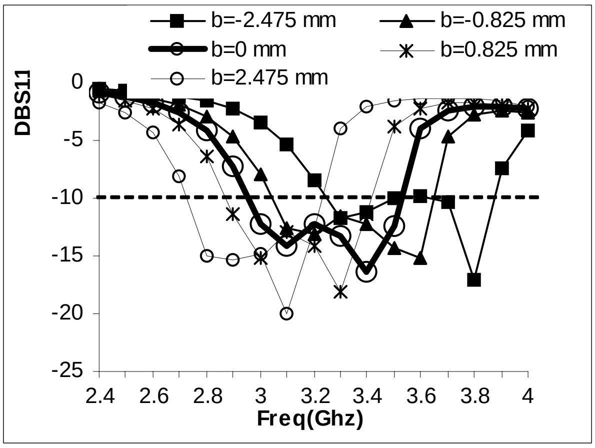
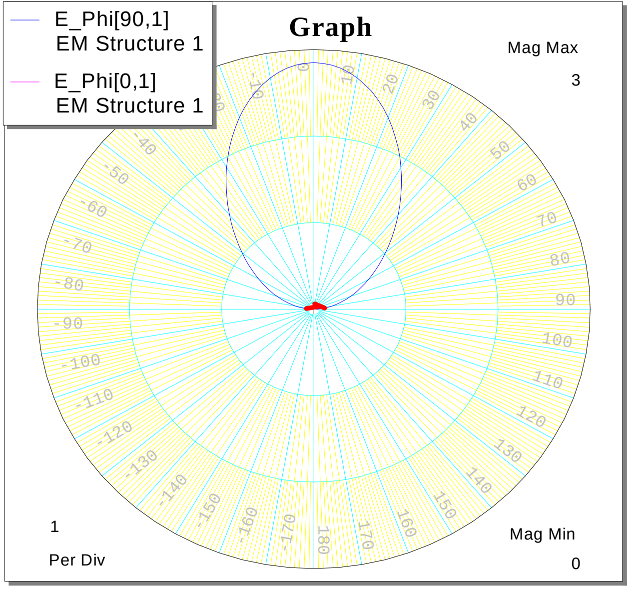


Fig. 6d. Results by changing the patch width (parameter b), while other parameters are fixed: d=2.475 mm, x=1.65, a=0 mm

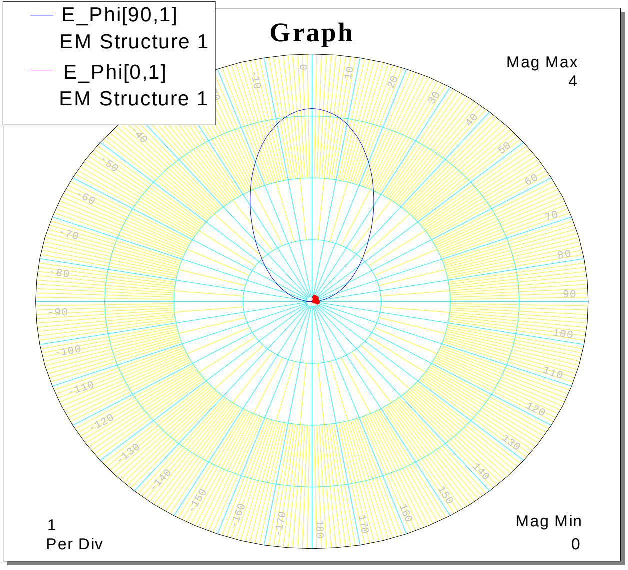
Based on above results the best solution is for: x=1.65 mm, d=2.475 mm , a≤ 3.3 mm , b>-2.475 mm

c.) Radiating pattern

The radiation patterns corresponding to an optimized case: x=1.65 mm, d=2.475 mm, a= 0 mm and b=0 mm, in both planes (Phi=0^o and Phi=90^o) are shown in Fig. 7 as functions of theta and for first resonant frequency, f=3.1 GHz. The case for the parasitic array with 5-element is shown in Fig. 7a while the case for the 7-elemnt is shown in Fig. 7b which shows a more directive pattern



a.)



b.)

IV. CONCLUSIONS:

In this paper, a parametric study for improving the bandwidth of several cross-shaped microstrip subarray antenna is presented using numerical simulation. Based on many simulations on our five-element cross-shaped subarray of microstrip patch antenna with various parameters, it is found that the bandwith can be improved to more than 18 %. Also, numerical results for the seven-element cross-shaped subarray antenna show similar improvement.

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