# A DUAL-FREQUENCY FEED NETWORK FOR DUAL-FREQUENCY MICROSTRIP ARRAYS

***Gui-Bin HSIEH[1], Chieh-Chin HUANG[2] and Kin-Lu WONG[2]**
**[1]Department of Electrical Engineering**
**Chinese Military Academy**
**Fong-Shan 830, Taiwan**
**[2]Department of Electrical Engineering,**
**National Sun Yat-Sen University**
**Kaohsiung 804, Taiwan**
**E-mail hsiehgb@ema.ee.nsysu.edu.tw**

## 1. Introduction

Dual-frequency operations of microstrip arrays have received much attention and some related designs have also reported [1-2]. The available designs are mainly associated with the use of two individual feed networks in different layers to excite separate radiating elements. In this article, we propose a new and simple dual-frequency network design suitable for applications in dual-frequency microstrip arrays with dual-frequency radiating patches [3]. The proposed dual-frequency feed network (see Fig. 1 for a $2\times2$ subarray case) is a corporate H-shape microstrip-line network consisting of 70.7-$\Omega$ microstrip-line sections as quarter-wavelength impedance transformers and 50-$\Omega$/100-$\Omega$ microstrip-line segments. In addition, at point h, the feed network is connected to a 50-$\Omega$ probe feed for the excitation of the dual-frequency subarray. It is found that by first designing the H-shape feed network to obtain impedance matching for either one of the two desired operating frequencies and then selecting an optimal length $a$ of the 50-$\Omega$ microstrip-line segments ($\overline{cf}$ and $\overline{jk}$; see Fig. 1) in the center of the H-shape network, good impedance matching for the other desired operating frequencies can also be achieved using the same feed network; that is, with the use of a single feed network, impedance matching at two separate operating frequencies can be obtained. However, since the two operating frequencies use the same radiating patch and good array gain can be obtained when the inter-element spacing between the patches in the array is within 0.6 to 0.9 free-space wavelengths [4], the proposed feed network is limited to applications of feeding a dual-frequency microstrip array with a frequency ratio between its two operating frequencies less than 1.5. One design example of the $2\times2$ dual-frequency microstrip subarray fed by the proposed dual-frequency feed network is presented and discussed.

## 2. Array Design

The geometry of a $2\times2$ dual-frequency microstrip subarray with the proposed dual-frequency

feed network is shown in Fig. 1. The radiating elements used in the array are circular patches with an arc-shaped slot and are printed on a substrate of thickness h and relative permittivity $\varepsilon_r$. The radius of the circular patch is D, and the arc-shaped slot is subtended by an angle $\theta$. By varying the length of the arc-shaped slot in the circular patch, dual-frequency operation with a tunable frequency ratio of about 1.29 to 1.43 between the two frequencies can be obtained [5]. The inter-spacings between the slotted circular patches in both x and y directions are denoted as S, and all the patches are uniformly excited. In order to obtain the optimal length $a$ of the 50-$\Omega$ microstrip-line segments of $\overline{cf}$ and $\overline{jk}$, the return loss, seen at point h, versus length $a$ for the microstrip subarray shown in Fig. 1 is calculated, and the measured input impedance at point b for a single-patch case is used for calculating the return loss. By using the $2\times2$ dual-frequency subarray shown in Fig. 1 as a basic building block, large dual-frequency arrays can also easily be implemented.

## 3. Results and Discussion

Three cases with $\theta$ = $88^o$, $92^o$, and $100^o$ are studied. The calculated return loss, seen at point h, versus length $a$ and the measured return loss versus frequency for the cases with $\theta = 100^o$ are shown in Figs. 2(a) and 2(b), respectively. In this case, the two operating frequencies are 2010 and 1567 MHz. The inter-element spacing S is first selected to be 134 mm, leading to a spacing about $0.9\lambda_0$ at the higher frequency 2010 MHz and about $0.7\lambda_0$ at the lower frequency 1567 MHz. Then, we first design the H-shape feed network to obtain impedance matching for the lower frequency $f_1$. The optimal length $a$ of the 50-$\Omega$ microstrip-line segments of $\overline{cf}$ and $\overline{jk}$ is determined to be 30.6 mm, where the calculated return loss seen at point h is about 24 dB [see the results in Fig. 2(a)] for the higher frequency $f_2$. On the other hand, the return loss at point h for the lower frequency $f_1$ is independent of the variation of length $a$ and is the same as the measured return loss at point b. With the optimal length $a$ selected, the dual-frequency subarray is implemented and the measured return loss is presented in Fig. 2(b). Good impedance matching at both the operating bands of 1567 and 2010 MHz is seen to be obtained and the measured return loss is all greater than 20 dB, which agrees well with the calculated results shown in Fig. 2(a). The measured radiation patterns for the case with $\theta = 100^o$ are plotted in Figs. 3(a) and 3(b) for f = 1567 MHz ($f_1$) and 2010 MHz ($f_2$), respectively. It is observed that owing to the array effect, the radiation patterns become narrower, compared to those of a single-patch case [5]. The side lobe levels (SLLs) in the E- and H-plane patterns for $f_2$, however, are seen to be greater than -10 dB. This characteristic can be improved, and better SLLs can be expected for larger arrays, because it is known that the SLL of an $N\times N$ array with uniformly excited elements will decrease with increasing N. Also, owing to the array effect, the on-axis antenna gains for the two operating frequencies are both found to increase by about 5.5 dB as compared to a single-patch case [5]. As for the two cases with $\theta$ = $88^o$ and $92^o$, similar dual-frequency performances are also obtained.

## 4. Conclusions

A new design of a dual-frequency feed network has been proposed and studied. By

incorporating dual-frequency radiating elements, dual-frequency arrays can easily be obtained by using the proposed dual-frequency feed network. However, the proposed feed network is limited to applications of feeding a dual-frequency microstrip array with a frequency ratio less than 1.5. This limitation is because the two operating frequencies use the same radiating patch and good array gain can be obtained when the inter-element spacing in the array is within 0.6 to 0.9 free-space wavelengths [4]. More related results will be presented and discussed.

## 5. References


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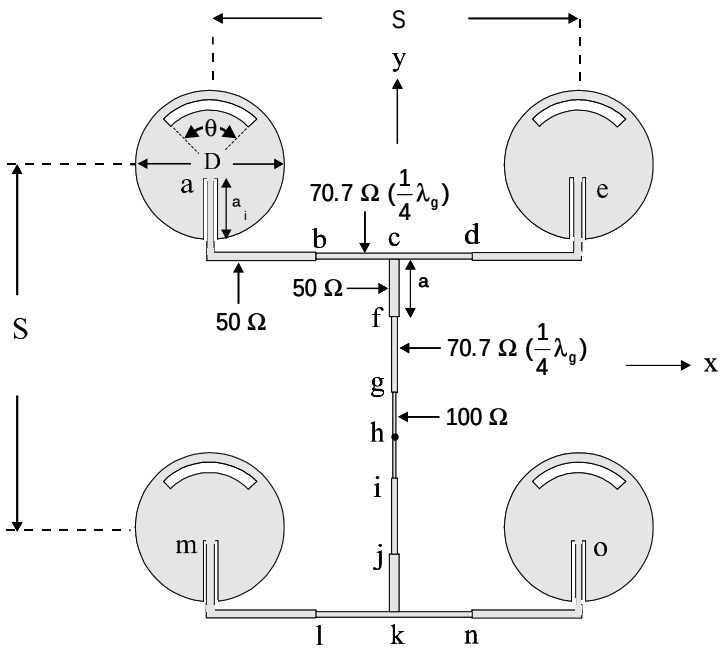


Fig. 1 Geometry of a $2\times2$ dual-frequency microstrip subarray with dual-frequency feed network and slotted circular patches.

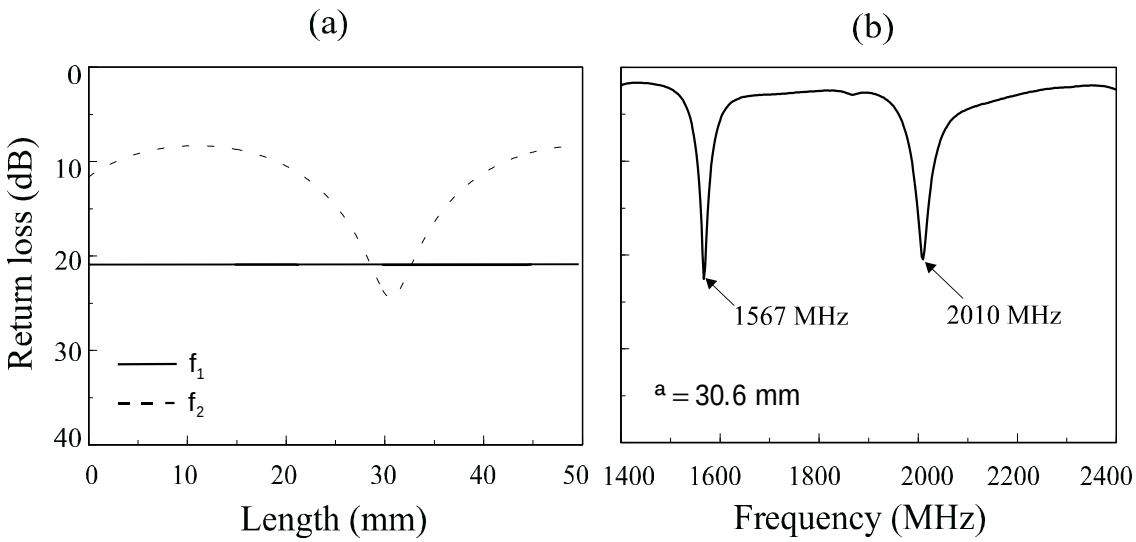


Fig. 2 (a) Calculated return loss, seen at point h, versus length a and (b) measured return loss versus frequency for the microstrip subarray in Fig. 1; $\varepsilon_r$ = 4.4, h = 1.6 mm, D = 50 mm, $\theta = 100^{o}$, $a_i$ = 37 mm, S = 134 mm. The measured input impedance at point b for a single-patch case is used for obtaining the calculated results shown in (a).

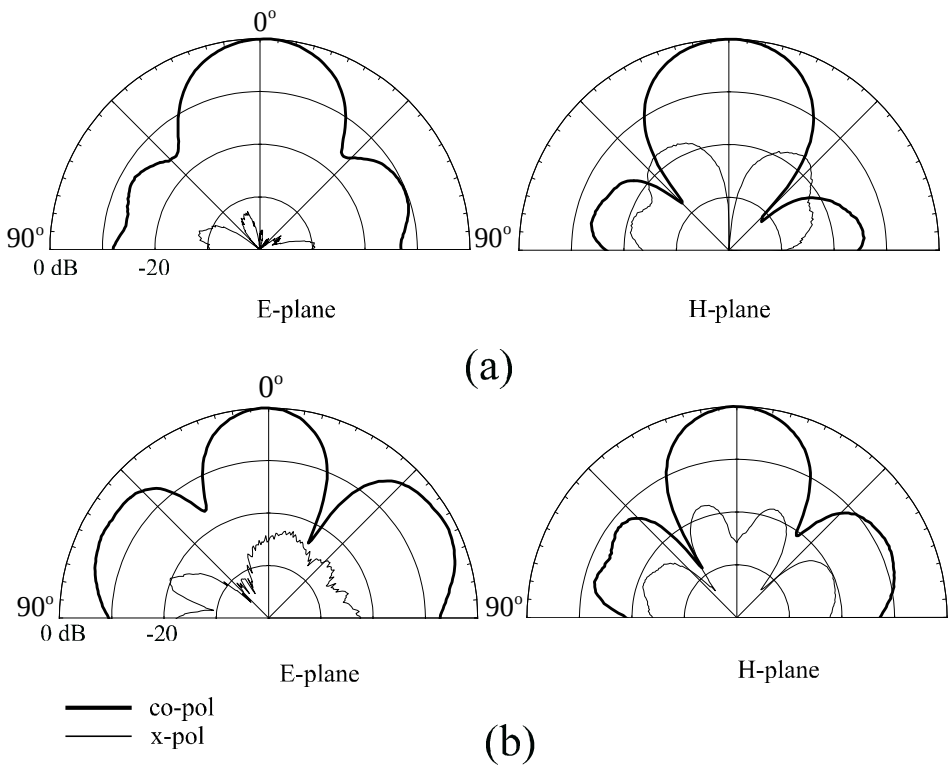


Fig. 3 Measured E-plane (y-z plane) and H-plane (x-z plane) radiation patterns for the dual-frequency microstrip array studied in Fig. 2. (a) f = 1567 MHz. (b) f = 2010 MHz.