無線通訊用積層陶瓷天線及濾波器

Wireless Antenna and Filter Employing Multi-layered Ceramic Technology

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本案第三年改良之成果，繼第二年所提前設計之筆形波束陣列天線，朝改良陣列天線之效率著手。將一般平面微帶線陣列天線之效率（不限於洩漏波陣列天線），從過去所僅能達成之30%左右，提升至目標值之90%。藉著新推導的理論及改良設計，我們一方面把原型設計之損耗降至最低，同時藉著增強洩漏波模之藕合，有效提升天線之截面積使用，使整體之天線效率大幅提升。該原型設計，實策測有84%天線效率在11.9GHz。此改良後之陣列天線，可適用於一般無線通訊系統，以提升整體效能。

Abstract - The first-pass design of an eight-element, closely coupled microstrip leaky-mode antenna array is proposed, built and tested, showing that the directivity of 20.1 dBi, gain of 19.1 dBi, and overall radiation efficiency of 79% is achieved.

I. INTRODUCTION

Recent years have witnessed a rapid growth of wireless communication systems such that an antenna plays a paramount role in establishing a communication link between different destination points. With diversified applications of wireless communications, there has been an increasing demand for more-sophisticated antennas. On one hand, such antennas must feature improved performance. On the other hand, they must fulfill a number of additional requirements, including attracting the commercial market. It turns out a significant move to replace conventional cumbersome parabolic antennas by low-profile, low-weight, and more-aesthetic antennas. One possible candidate is the microstrip-array antenna, as it has a number of the desired features such as a low profile, low weight, and relatively low cost to develop. One problem with this antenna, however, is the lack in efficiency when the required gain value is high. Recently, Ando, et al. [1]-[3], proposed a variety of RLSAs (radial line slot antennas) by employing very low loss parallel plate waveguide and achieved as high as 85% antenna efficiency. Malherbe [4] reported a novel antenna of NRD (nonradiative dielectric) array, showing almost 100% of aperture efficiency, excluding the power loss in the load. These designs, however, are not realized in the printed-circuit form, needing extra transition circuit to interface to typical transceiver front ends. Hu and Tzuang [6] reported a novel microstrip leaky-mode antenna array in which a pencil beam can be produced by employing a linear, one-dimensional array such that the loss and complexity of the feeding network can be greatly reduced. This conformal planar printed array can easily and efficiently integrates with transceiver front ends, however only about 30% of efficiency is obtained. This drop in efficiency is partly due to loosely coupled microstrips so that part of energy be reflected back to space rather than be captured by radiating elements. To enhance the radiation efficiency of the microstrip leaky-mode array, this report reports a high efficiency, closely coupled microstrip leaky-mode antenna array in which the microstrips are tightly placed such that more radiating elements can be accommodated and high efficiency can be attained. To rigorously analyze the mode-coupling of leaky modes inhering in the array, the coupled-mode approach [7] is used. Therfore the investigation of a corporate-fed, eight-element array can be viewed and designed by the modal analysis, explicitly revealing the guide waves aspect of the closely coupled leaky-mode array. Finally, an experimental 8-element microstrip leaky-mode array

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II. Closely Coupled Microstrip Leaky-Mode Array Design

The linear microstrip leaky-mode array is fabricated on a 20-mil (0.0508 cm) thick RO4003 substrate with relative permittivity of 3.38. For a single microstrip leaky-mode antenna as shown in Fig. 1(a), the width and length of the microstrip is properly chosen such that leaky-mode emission can be attained and a clean main beam points to the specified direction. In Fig. 2, the dispersion characteristic of EH_1 mode for the single microstrip against frequencies is plotted in the solid-line with circle symbol. The mode-coupling of complex waves in Fig. 1(b) is analyzed by coupled-mode approach, presenting the fact of N coupled leaky modes existing in an N-element microstrip array. Eight coupled EH_1 modes for an eight-element closely coupled microstrips are computed and plotted by the dot-lines as shown in Fig. 2. The contribution of each coupled EH_1 modes to the radiation far-field pattern is determined by the excitation at the feeding network. As shown in table I, only four out of eight coupled EH_1 modes have contribution, where one mode is dominant for the corporate-fed array. The dispersion characteristic of the dominant coupled EH_1 mode are high lighted by the solid lines, showing that the α/ko value of the dominant coupled EH_1 mode is increased about 20%-70% as compared to that of a single microstrip but the β/ko value is changed by about 0%-10%. This implies that the back-lobe is significantly reduced and half-power beamwidth is increased while the main beam can almost be kept in the specified direction. From the modal spectrum analysis of the closely coupled microstrip array as shown in the Fig. 2, the array length of 6.5 cm will result in more than 90% of radiated power. The beam point angle ($\theta_s=\sin^{-1}(\beta/ko)$) and percentage of power radiation ($P_{rad}\%=(1-e^{-2\alpha L})\times100$) corresponding to a single microstrip and closely coupled microstrip array are plotted in Fig.3, respectively. As expected, for the single microstrip, less power is radiated and the antenna efficiency suffers significantly as frequency increases. However, for the closely coupled array, most of power is radiated to ameliorate the antenna efficiency. Most importance implied in Fig. 3 is that the α/ko value is possible to be tapered for better aperture distribution by this approach since the α/ko value can be modified in some range while β/ko is almost kept constant [5]. Finally, an experimental prototype is built and tested. The photo of the experimental array is shown in Fig. 5, in which the matching circuit is merged into the corporate feed to excite the coupled EH_1 modes with a very compact fashion. Thus, each radiating element receives/transmits equal amount of power.

III. Measured Results

Three major performance indexes are measured. They are 1) the degradation of input matching as the result of effect of strongly mutual coupling, 2) the reduction in back-lobe and increase in half-power beamwidth, and 3) the antenna gain.

Fig 5 plots the measured $|S_{11}|$ at the input port of the array, showing VSWRs less than 2.0 ($|S_{11}|<-10$ dB) for the frequency band between 11.4 and 12.4 GHz. Unlike the significant degradation on the input impedance due to the mutual coupling for the patch array, the VSWR bandwidth of 8.5% is easily achieved.

Fig. 6 plots the measured far-field patterns along the H-plane ($\phi=90°$), showing that the back-lobe is reduced from –8 dB (single element) to –12 dB (array) and half-power beamwidth is enlarged by 42%. As the length of the strip changes from 5cm to 6.5cm (30% increase), the half-power beamwidth almost coincides to that of a single microstrip and the back-lobe can be further reduced to –20 dB. This implies that the agreement between measured α/ko value and the predicted result as shown in Fig. 2 is acceptable. The cross-polarization pattern is also measured and plotted in Fig. 6, showing -18 dB below the peak radiation power throughout the measurement, and demonstrating negligible cross-polarization.

Fig. 7 shows the measured antenna's gain and overall radiation efficiency, showing that the maximum efficiency of 79% at gain of 19.1 dBi is achieved at the frequency of 11.6 GHz.

IV. Conclusion

A first-pass design of a proposed closely coupled microstrip leaky-mode antenna array is presented. Excellent measured results show that the new printed antenna array is feasible for high efficient antenna design.

IV. Acknowledgment

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TABLE I. The Amplitude and Phase of Excited Coupled EH_1 Modes

Mode No.	1	2	3	4	5	6	7	8
Mode Amp./ Phase	2.67/ 0°	0./ 0°	0.82/ 106°	0.0/ 0°	0.4/ -74°	0.0/ -0°	0.17/ -72°	0.0/ 0°

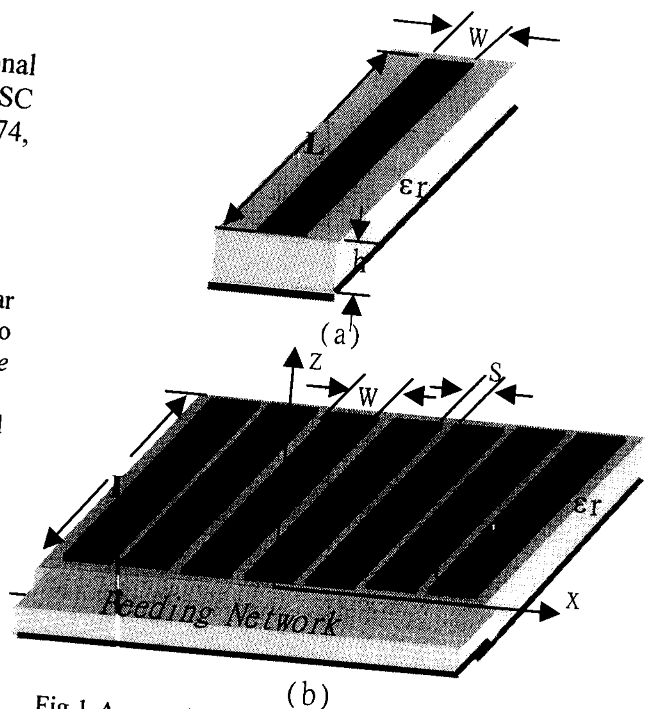

Fig.1 A generic, (a) single microstrip leaky-mode antenna, (b) coupled microstrip leaky-mode array of eight elements

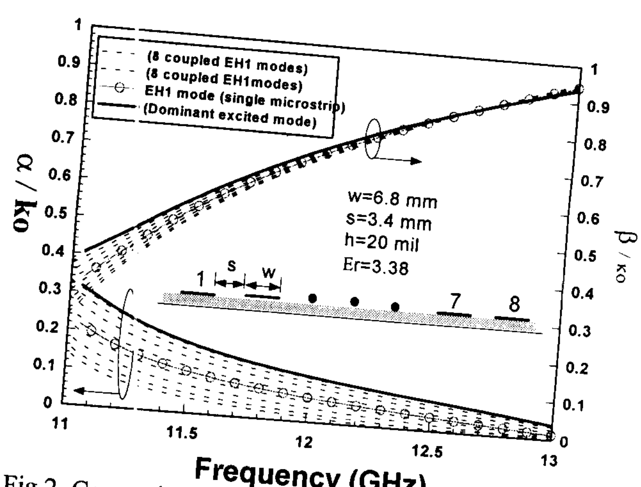

Fig.2 Comparison of dispersion characteristics of a single microstrip line and those of the 8-element coupled EH_1 modes

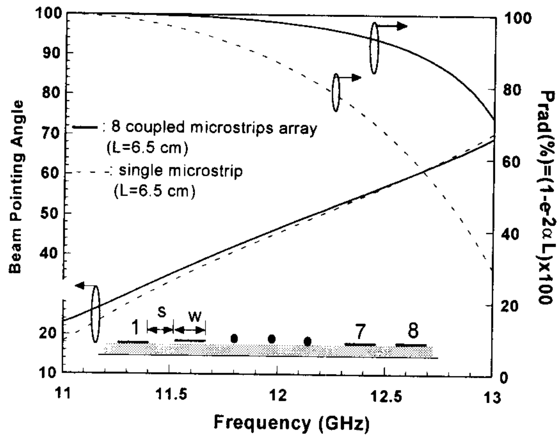

Fig. 3 Curves of beam pointing angle (θ_m) and percentage of radiated power (P_{rad} %)

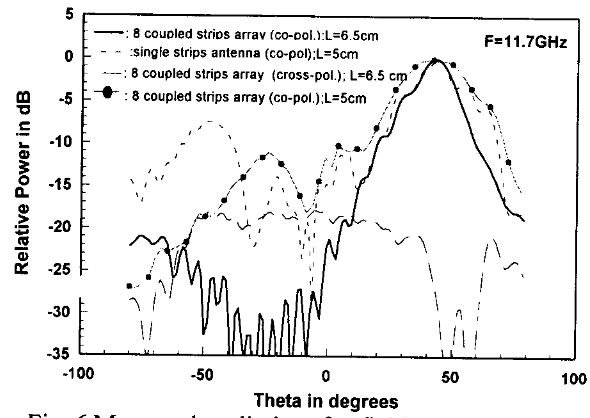

Fig. 6 Measured radiation far-field patterns along H-plane.

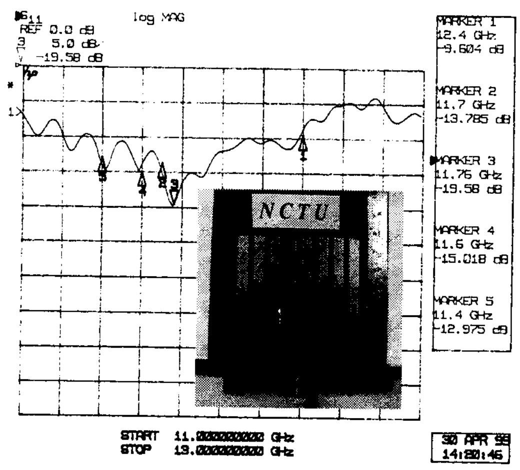

Fig.4. The measured magnitude of S_{11} against frequencies of interest.

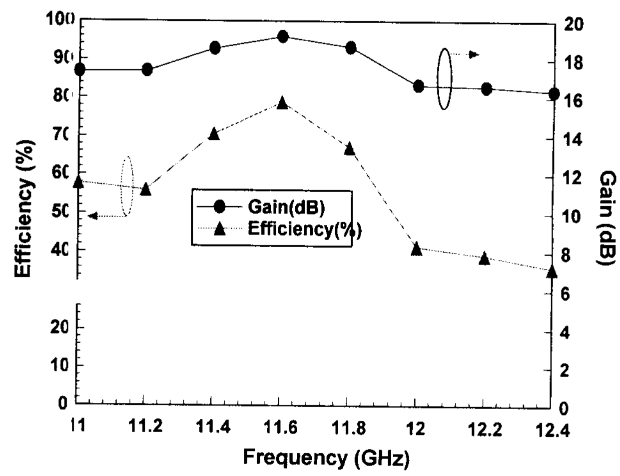

Fig. 7 The measured antenna gain and overall efficiency of prototype microstrip leaky-mode array as shown in Fig. 5

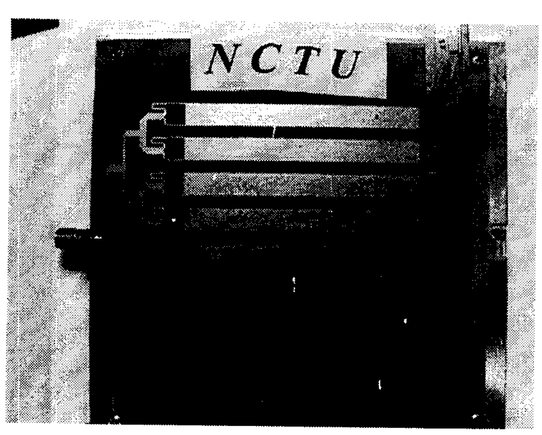

Fig.5. The photo of prototype eight-element microstrip leaky-mode array

V.