A BROADBAND ANTENNA OF DOUBLE-SIDED PRINTED STRIP DIPOLES

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1. Introduction

Arrays of dipole antennas backed by a plane or corner reflector offer practical as well as simple solutions for base station applications. Very often strip dipoles printed on an electrically thin dielectric substrate are used to achieve the advantages of printed circuit fabrication. Arrays of these antennas require more depth than those using microstrip antennas, but they generally offer more bandwidth [1]. In another configuration, strip dipoles with the elements printed on both sides of a thin dielectric substrate have been used for the realization of flat arrays with bandwidths up to 25 percent [2]. However, broadband impedance matching becomes difficult when printed dipole elements are placed close to a plane or corner reflector which is usually employed in sector zone base station antennas of public mobile radios.

This paper presents a broadband antenna suitable to be used as a radiating element in front of a plane or corner reflector. It consists of two double-sided printed strips connected through a balanced stripline. A microstrip-balanced stripline tapered transition [2] can be used to feed the antenna from an unbalanced coaxial connector. These antennas can be employed in sector zone base stations where a relatively wide frequency band must be covered, such as the $900MHz$ band of the Japanese cellular system or the third generation mobile systems (FPLMTS). A simplified analysis method based on the generalized concept of equivalent radius of cylindrical antennas [3] and a moment method is also described and used to design antennas with impedance bandwidths up to 30 percent for $VSWR \leq 1.5$. Theoretical and experimental results for various antenna configurations are presented.

2. Antenna configuration and analysis model

The antenna under consideration is illustrated in Fig. 1(a). Two narrow strip dipoles of lengths $2L_1$ and $2L_2$ with arms printed on both sides of an electrically thin dielectric substrate are spaced at a distance d and connected through a balanced stripline of characteristic impedance Z_0. As shown, this represents a standard series-fed array of two strip dipoles. The longer and shorter dipoles are made to resonate slightly below and above the nominal center frequency, respectively, but both dipoles radiate effectively over the operating band. One objective of this design is to maximize the impedance bandwidth around the design frequency f_0. Another objective is to have a condition for endfire radiation from the dipoles. For this purpose, the direct connection is employed since it gives the necessary phase progression for endfire radiation. To meet the specified performance criteria, however, all of the available parameters must be optimized. This requires a CAD modeling of the antenna. Since this presents a complex problem and the number of parameters is large, a full wave analysis may be computationally expensive and time consuming. In the case of narrow strips printed on an electrically thin dielectric substrate, however, a simplified model using approximately equivalent coated wire antennas [3] can be employed. This approach proved to give quite good results when used to design similar antennas of double-sided printed strips [4].

The equivalent model used to analyze these antennas is illustrated in Fig. 1(b). The printed strip elements are transformed to that of circular wires with coaxial magnetic covers based on the quasi-static energy equivalence conditions. The effect of magnetic coating can be represented as a series impedance per unit length under the quasi-static approximation. The equivalent antenna can be analyzed with the usual method of moments for wire antennas that has the facility to include an arbitrary impedance per unit length. The effect of the connecting line is incorporated by using standard equations for transmission lines. As shown in Fig 1(b), the complete antenna system can be considered as two two-terminal networks. First, the radiating elements with the self and mutual impedances, and secondly the transmission line with the terminals at the dipole drive points. In this way the terminal voltages and currents can be computed, and hence the performance of the antenna.

3. Numerical and experimental results

Using the analysis model described above, an antenna printed on a dielectric substrate of height $h = 0.8mm$ and permittivity $\epsilon_r = 2.2$ has been designed to maximize the impedance bandwidth around the design frequency $f_0 = 2GHz, \lambda_0$. An optimal design has been obtained by choosing $L_1 = 0.24\lambda_0$, $L_2 = 0.2\lambda_0$, $d = 0.2\lambda_0$, $Z_0 = 120\Omega$, while $w_1 = w_2 = 4mm$ have been used as constant parameters. The antenna was fabricated, tested, and compared with calculated results. Fig. 2(a) shows the measured and calculated results for the input return loss of this antenna. The measured $VSWR \leq 1.5$ bandwidth extends from $1.75GHz$ to $2.34GHz$ for a fractional bandwidth of 29 percent. The results are in good agreement with theoretical predictions. In Fig. 2(b), the calculated H-plane radiation patterns for four different frequencies are plotted, showing a typical behavior of an endfire array of two antenna elements.

Next, the above designed series-fed array of two printed strips was placed $0.2\lambda_0$ above a plane reflector as shown in Fig. 3 and its characteristics were calculated and measured. Fig. 3(a) shows the measured and calculated results for the input return loss of this antenna configuration. Again good agreement between measured and calculated results is observed and broadband impedance match maintained. The measured and computed H-plane radiation patterns at $2.04GHz$ are shown in Fig. 3(b). The agreement between calculated and measured patterns is excellent.

Finally, the characteristics of two coupled series-fed arrays spaced $0.5\lambda_0$ and placed above a plane reflector as shown in Fig. (4) were investigated. In fig. 4(a), the calculated results for scattering parameters of this configuration are compared with experiments, showing good agreement. In addition to the broadband performance, a relatively low level of mutual coupling between two arrays is observed. In Fig. 4(b), the measured and computed H-plane radiation patterns at $2.04GHz$ are plotted. The agreement between two results is excellent. It must be mentioned that this antenna has almost the same half-power beamwidth in the H-plane over the operating frequency band.

4. Conclusion

An antenna of two double-sided printed strip dipoles connected through a balanced stripline has been designed to maximize the impedance bandwidth near the nominal design frequency. It has been demonstrated that a bandwidth of 30 percent for $VSWR \leq 1.5$ can be achieved with this simple antenna configuration. This design could be useful as a radiating element in a sector zone base station antennas. A simplified analysis model to design these antennas has also been presented. Good agreement between calculated and measured results confirm the validity of the model.

References:

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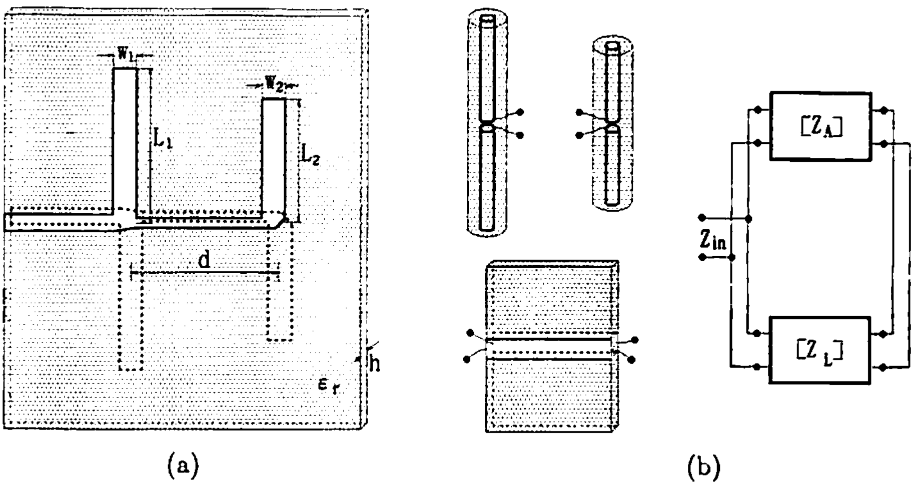

Fig. 1 (a) Geometry of a series-fed array of two double-sided printed strips. (b) Equivalent analysis model and its schematic plan.

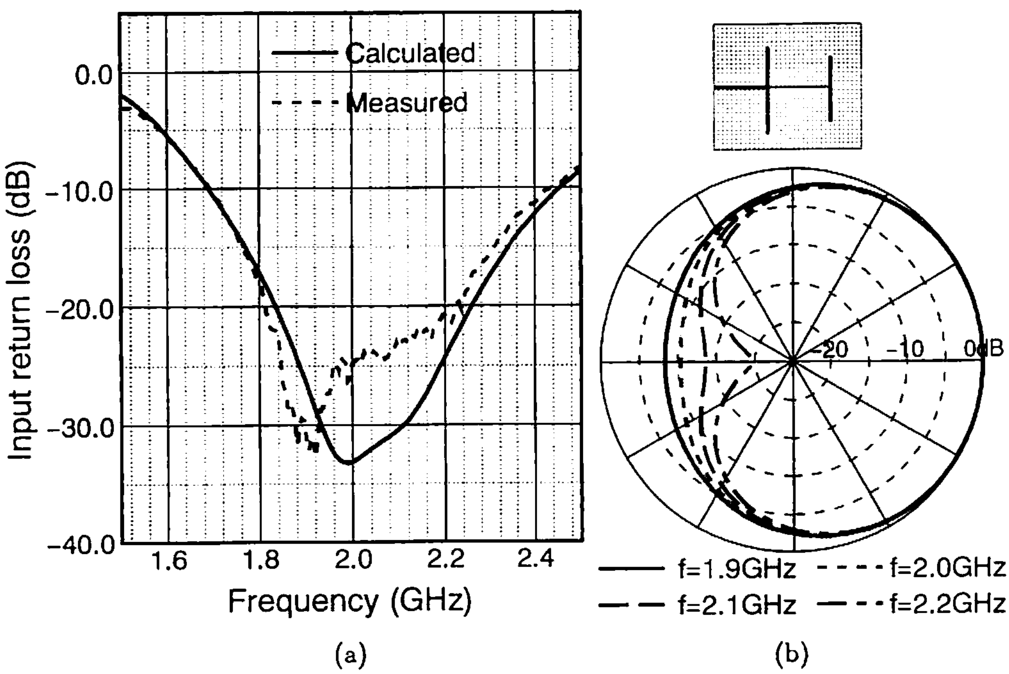

Fig. 2 Series-fed array of two double-sided printed strips. (a) Measured and calculated input return loss. (b) Calculated H-plane radiation pattern.

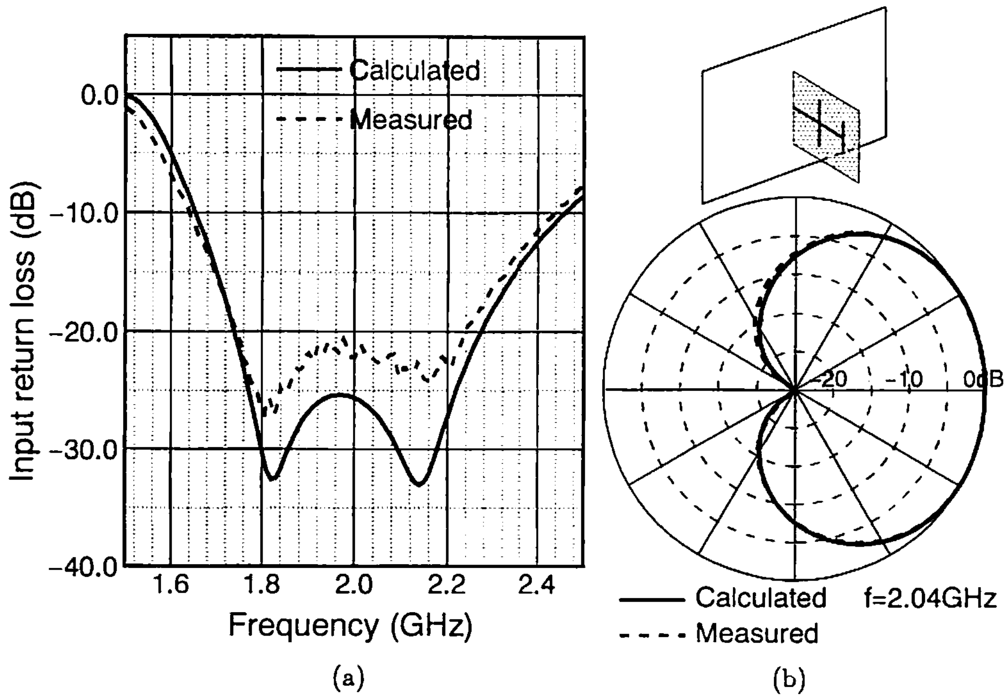

Fig. 3 Series-fed array placed above a plane reflector. (a) Measured and calculated input return loss. (b) Measured and calculated H-plane radiation patterns at $2.04GHz$.

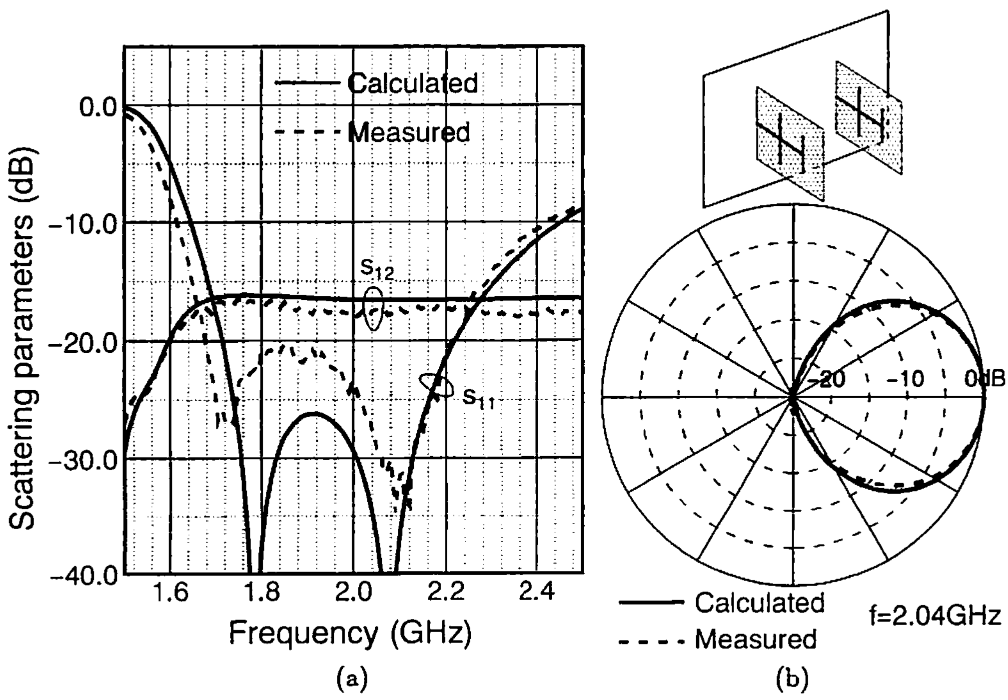

Fig. 4 Two coupled series-fed arrays placed above a plane reflector. (a) Measured and calculated scattering parameters. (b) Measured and calculated H-plane radiation patterns at $2.04GHz$.