IMPEDANCE CONTROL OF MICROSTRIP ANTENNAS UTILIZING REACTIVE LOADING

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ABSTRACT

A study has been undertaken to determine the feasability of dynamically controlling the input impedance of a microstrip antenna element by changing its reactive loading. The major applications of such an element would be for use in a scanned phased array. By changing the loading of individual elements appropriately, one could alter the active array impedance of the elements to compensate to some degree for the onset of scan blindness. While the ultimate feasability of such applications cannot yet be firmly established, a single element can be controlled using PIN diodes to effectively alter its input impedance. The generalized theory of loaded microstrip antennas has been used to predict the impedance of a variety of microstrip, antenna configurations with multiple loads. This work has shown the possibilities of changing the input impedance of the radiator over a wide range of values without affecting its resonant frequency or radiation pattern by moving a set of short-circuited loads from one position to another. Actual printed-circuit antennas were fabricated based on this design and good correlation was found between theory and experiment.

INTRODUCTION

For design purposes it is necessary to have a simple theory which describes the physical mechanisms of the microstrip antenna. One theory that has proven to be very physically illuminating, and relatilvely accurate as well, is the cavity-model analysis. This technique has been used previously to predict the electrical behavior of both loaded and unloaded microstrip, radiators. It has been applied in the design of loaded elements for other applications(1,2). Limitations in space prohibit the inclusion of the details of the analysis, but this work has been previously reported by Richards and Lo(3) and associated work by Richards, *et al.*(4) Using these techniques the resonant frequency and input impedance for a microstrip antenna with multiple reactive loads can be calculated and used in the design procedure for the radiators under investigation.

APPLICATION TO IMPEDANCE MATCHING AND RESULTS

The overall objective in this application is to vary the input impedance *while keeping the resonant frequency and pattern of the element fixed*. This objective can be met by placing short circuits at one or more appropriately chosen locations on the patch. These short circuits can be PIN diodes (thus allowing adaptation of the element to changing conditions such as the scan angle in a phased array).

As seen in previous work(3), one can vary the resonant frequency by varying the location of a short-circuiting pin. It is also possible to vary the input impedance with a single short circuit without altering the resonant frequency. The input impedance can be varied for a *fixed* feed location as the *nodal line* of the loaded resonant mode is modified by moving the shorting pin location. The closer the nodal line is moved to the feed, the lower the peak input resistance will be. It is necessary, however, to move the shorting pin in such a way that the resonant frequency is unchanged. This was done using an interactive computer program with graphical output based on the previously mentioned theory of loaded microstrip antennas.

The results indicated that if a single short circuit were placed on the proper locus, then the resonant frequency of the resulting loaded elements should be identical. The input impedance is show in in Fig. 1 for an element with a short circuit placed at one point along the locus illustrated in Fig. 2. This figure contains the computed magnetic current distribution, the computed input impedance, and the measured input impedance of the loaded element whose patch dimensions were 4.00 cm wide by 6.00 cm long by 0.158 cm thick. The dielectric substrate was 3M Corporation’s glass reinforced, double-clad PTFE. The manufacturer-supplied nominal dielectric constant was 2.43. The feed point was always at (1.00, 1.00), where the coordinates represent the distance in cm from a reference corner of the patch. This result is typical of all of the results obtained for a single short cirucit except that the size of the roughly circular impedance locus grew or shrank depending on the location of the load.

It is clear from Fig. 1 that the magnetic current distribution around the edge of the patch is asymmetrical. The pattern that results from such a distribution will have a significant cross-polarized pattern although the *E*-plane pattern will be typical of the (0,1)-mode of a rectangular element. This cross-polarization arising when a single short circuit is used is significant and probably unacceptable in many applications. Because of this, at least two short circuits should be used in symmetrical locations. In addition, the impedance range obtained is not extremely broad for a single-loaded element. The theoretical resistance *R versus x*, where *x* is the x-coordinate of a single short circuit placed along the locus illustrated in Fig. 2 is plotted in Fig. 3.

With *two* short circuits located symmetrically with respect to the long center line of the patch one can eliminate the undesired cross-polarization in the *H*-plane, and one can more easily obtain a wider variation of input impedance. Figure 4 shows the theoretical magnetic current distribution, and the measured and computed input impedances of a representative element loaded by a symmetrically located pair of short circuits. The locus of points on which these pairs of short circuits should lie is illustrated in Fig. 5. It is clear from the plot of resonant resistance *versus* the *x*-component of the load location illustrated in Fig. 6 that the impedance variation is greater for the double-loaded element than for the single-loaded element.

CONCLUSIONS

This investigation has shown that it is possible to change the input impedance of a microstrip element over a wide range without affecting its resonant frequency or co-polar pattern by moving short circuits from one point to another. This theory has been corrborated by experiment, and specifically, it was shown that the resonant frequency of the mode is left relatively unchanged by the appropriate placement of short circuits. The experiment also shows that the agreement between the predicted and observed input impedance is excellent in most cases. Finally, there was qualitative agreement between theoretical patterns and measured patterns although the measured cross-polarized components in the double-loaded element were higher than expected from the theory. From the dual points of view of producing lower cross-polarization and of more easily varying the impedance level over a wide range, two short circuits were seen to be better than one.

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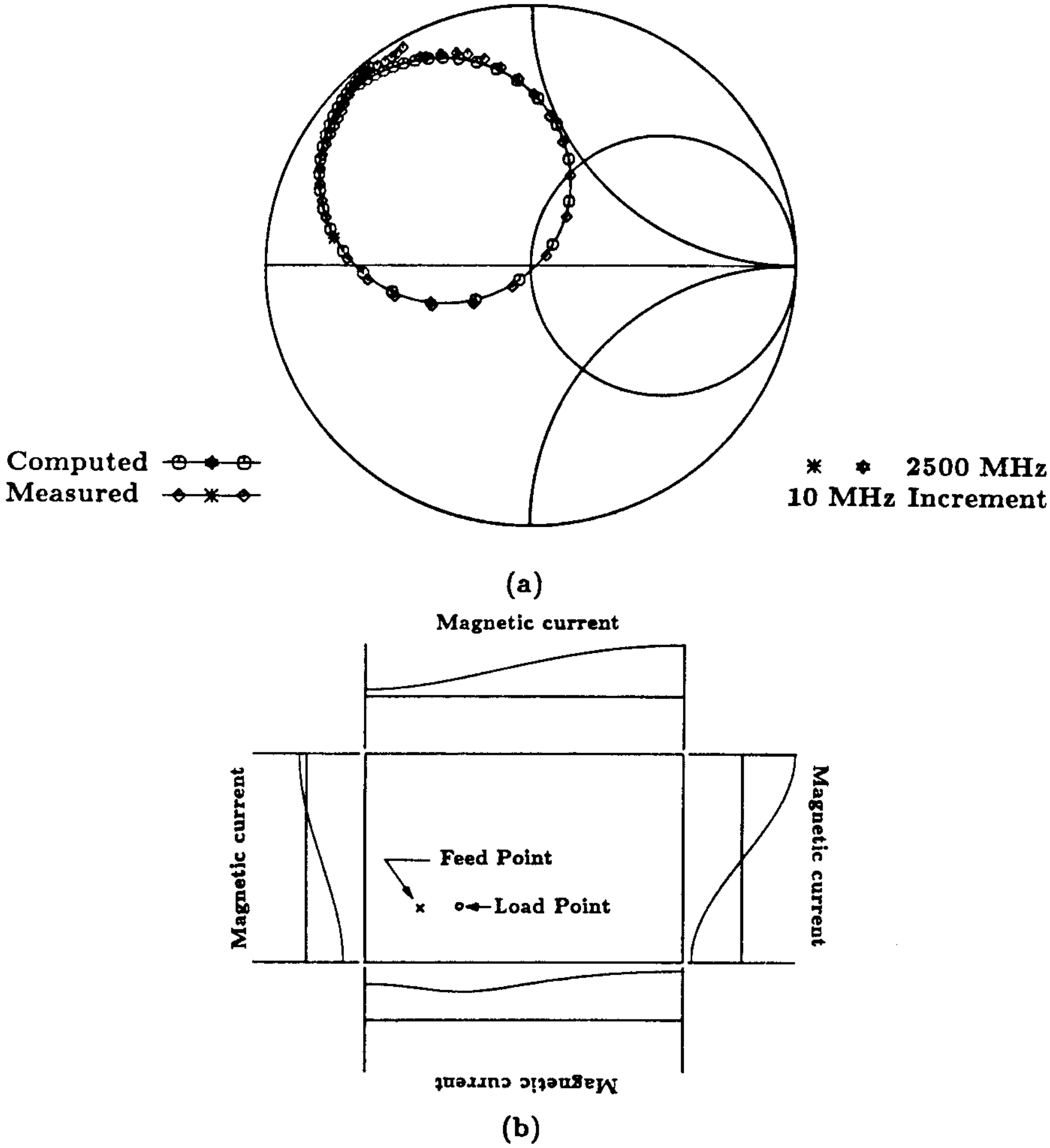

Fig. 1. (a) Measured and computed input impedance of a single-loaded element with short circuit at (1.75, 1.04). (b) Theoretical magnetic current distribution.

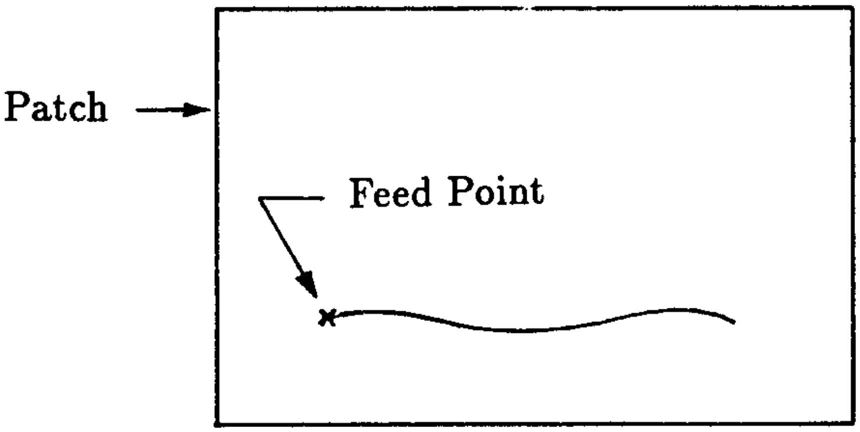

Fig. 2. The locus of short-circuit locations for constant resonant frequency of the single-loaded element.

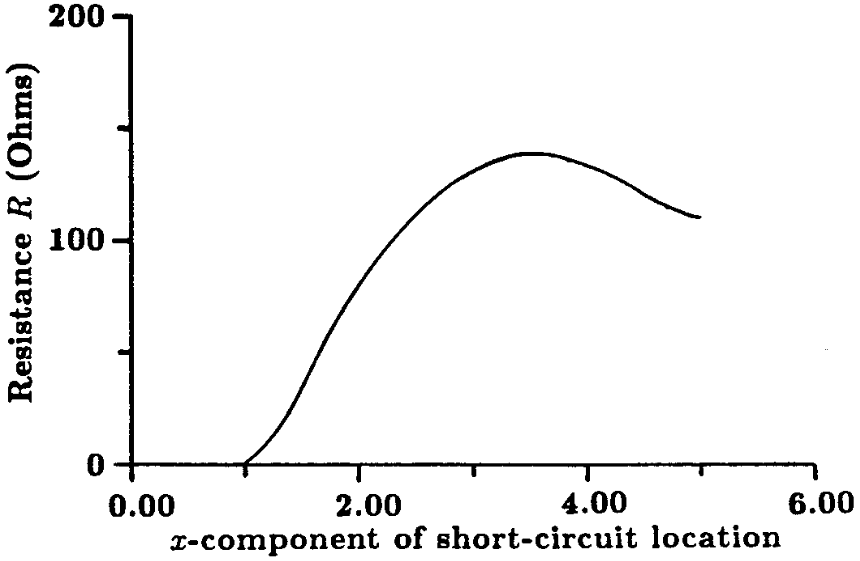

Fig. 3. The variation of the conductance *G* with the *x*-coordinate of a short-circuit position taken from the constant resonant frequency locus for a fixed feed at (1.00,1.00).

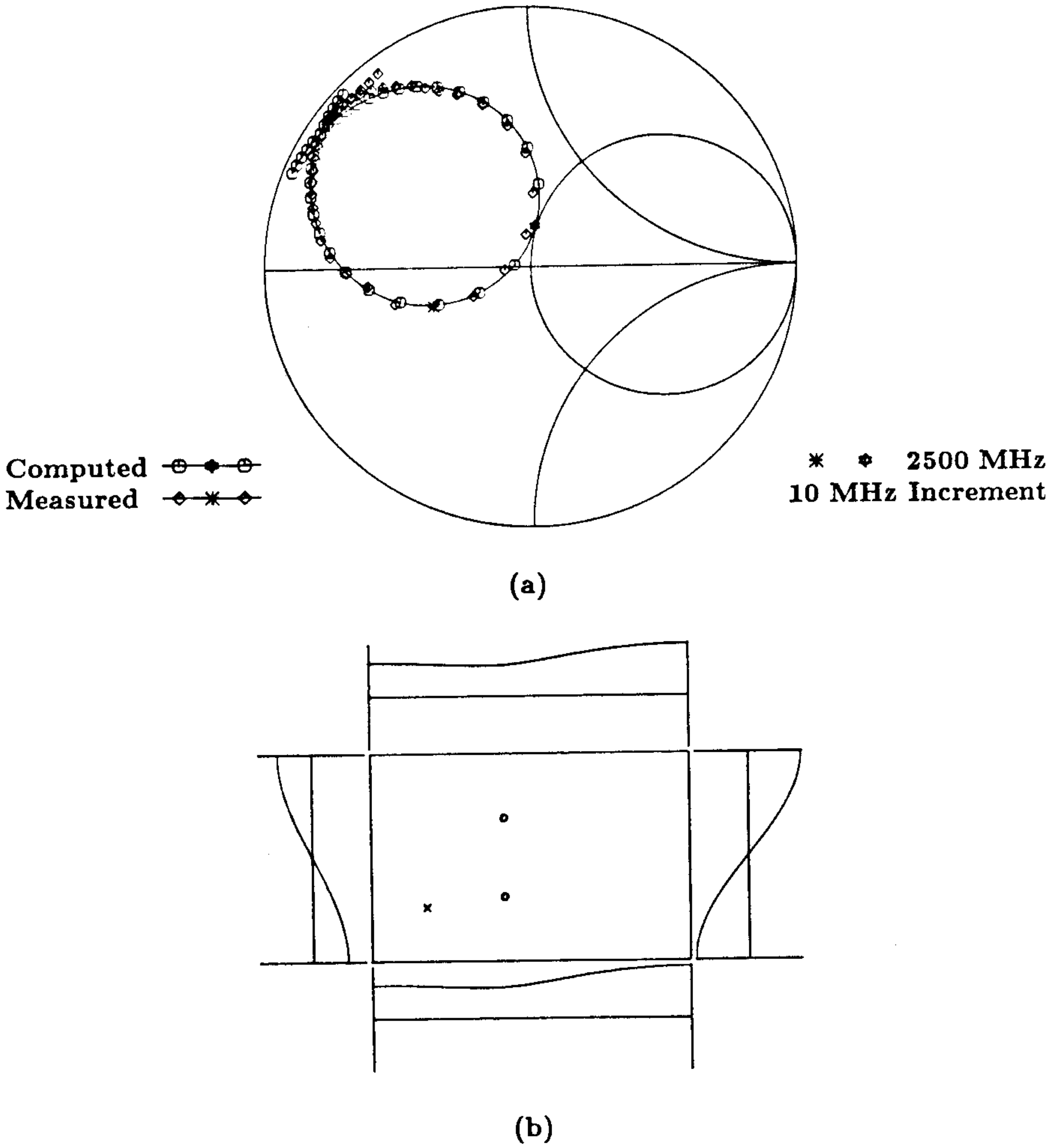

Fig. 4. (a) Measured and computed input impedance of a double-loaded element with short circuits at (2.50,1.21) and (2.50,2.79). (b) Theoretical magnetic current distribution.

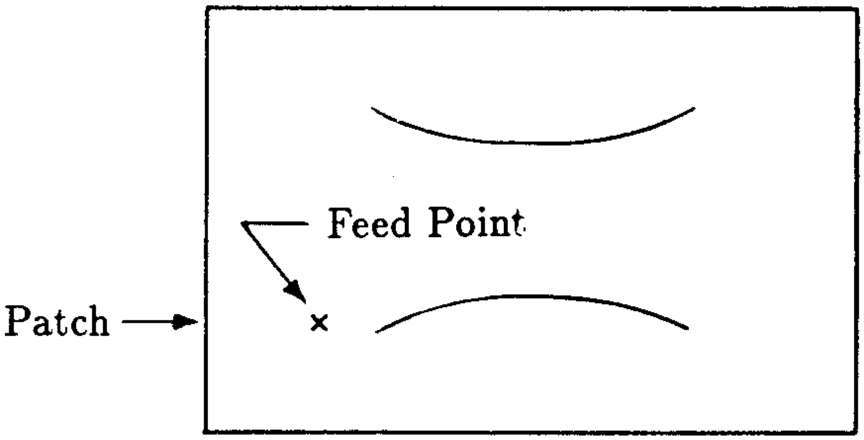

Fig. 5. The locus of short-circuit locations for constant resonant frequency of the double-loaded element.

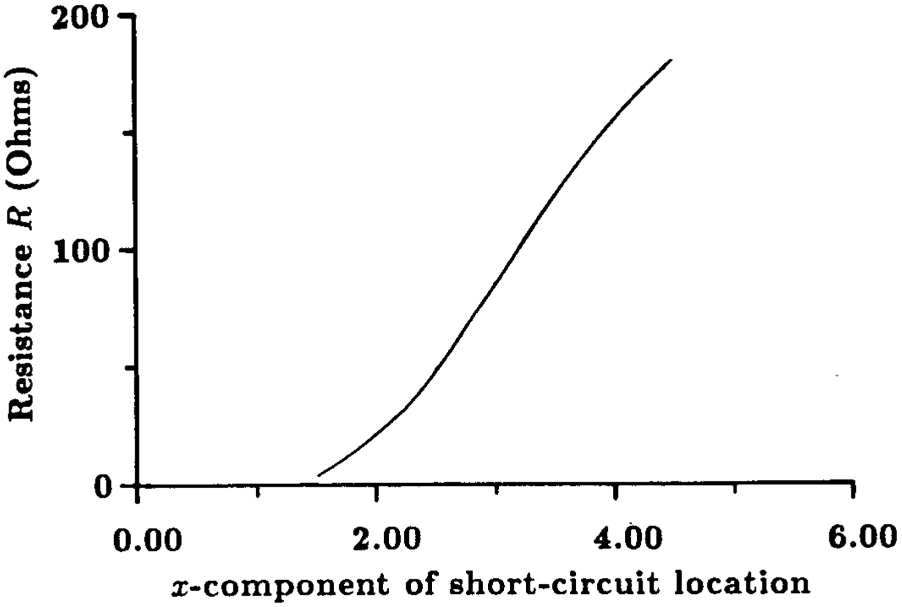

Fig. 6. The variation of the conductance *G* with the *x*-coordinate of a short-circuit position taken from the constant resonant freuqency locus for a fixed feed at (1.00,1.00).