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A Novel Frequency Pattern Enhancement Technique Based on Capacitively Coupled Microstrip Line Feed

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***Abstract*— A novel parallel-coupled microstrip feed line is proposed. The feed relies on the capacitance contribution arising from the capacitances occurring at adjacent split sections in order to lower the high intrinsic input impedance common to microstrip patch antennas. It is expected that the capacitance contribution will enhance the frequency pattern of the microstrip passive and thus overcome the narrow bandwidth tendency of the traditional patch. The novel feed has demonstrated enhanced impedance bandwidth, and the results have been validated theoretically, numerically and by measurement.**

Keywords—capacitive-coupled, capacitance contribution, feed line, split sections

I. INTRODUCTION

Microstrip patch antennas have demonstrated valuable premiums, among others non-disturbance of the aerodynamic flow, conformable structure with non-inward protrusion to hinder mechanical structure, simplicity, ease of integration with monolithic microwave circuits, capability of wide application to other devices, etc. However, they have also demonstrated a narrow frequency pattern, in particular owing to high input impedance. Several novel alternative solutions have been proposed to reduce the input impedance in order to enhance the frequency pattern. For instance, quarter-wavelength feed, inset feed and gap coupling have been proposed to overcome the substantial input impedance of the microstrip passives [1]-[5]. While these alternative solutions have led to incremental enhancement, the solutions are without side effects. We therefore introduce a novel split but capacitively coupled feed line expected to be gap-coupled to the radiator.

II. THE OPERATIONAL PRINCIPLE

Fig. 1 demonstrates the geometry of the proposed feed. The feed mechanism relies on capacitive contributions between the adjacent sections of the parallel-coupled split passives in addition to the capacitance owing to the gap coupled. The proposed feed illustrates the coupling that takes place between adjacent sections of the parallel-coupled structure. Each 0.5λ wavelength section of the coupled line network exhibits continuous coupling between two transmission lines that are parallel and in close proximity to each other but with no dc connection between the sections, as demonstrated in Fig. 2. The microstrip lines are in one plane and parallel to each other, and the parallel-coupled line is therefore described as an edge-coupled circuit. The separation between the lines is represented by δ, and the width of the lines in the coupling region is w_1. In general, this width is different from the widths

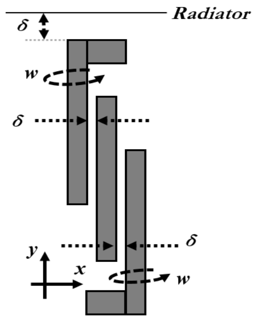


Fig. 1. The proposed microstrip feed line.

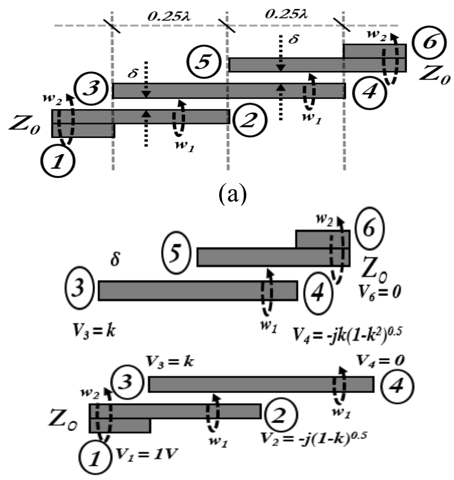


Fig. 2. Operation dynamics of the feed. (a) The parallel-coupled section, (b) The driving equations [6]

TABLE 1: RESPECTIVE NET POWER OUTPUT

Ports	*Power*
1	$\|(k^2-1)+k^2)\|^2$
2	0
3	0
4	0
5	0
6	$\|-2jk(k^2-1)^{0.5})\|^2$

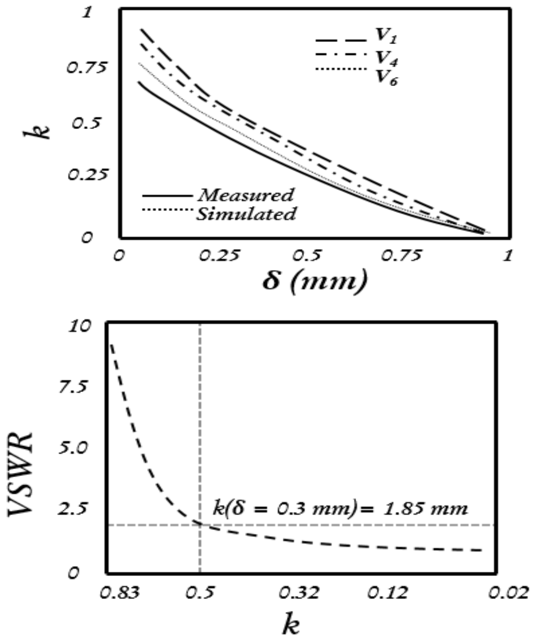


Fig. 3. Characterisation results of the feed line. (a) Coupling coeff. (k) vs spacing (δ), (b) VSWR vs δ [6]

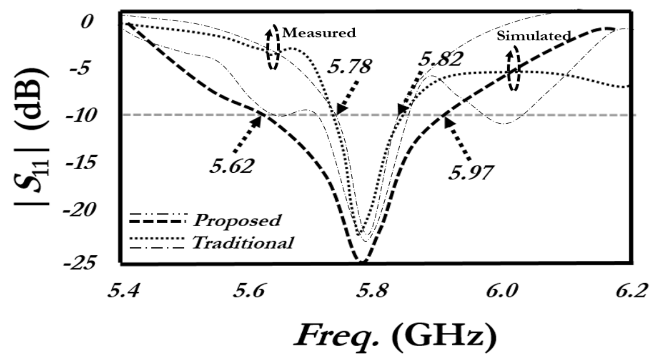
of the connecting lines at the ports, which will be denoted as w_2, for a 50 Ω characteristic impedance system (Z_0). The input at each port is matched to the feed line characteristic impedance irrespective of the electrical length of the coupling region. Port 1 is the input port, with ports 2, 3, and 4 being the direct, coupled, and isolated ports for the first quarter wavelength parallel-coupled structure shown in Fig. 2. Port 4 is always maintained at zero output irrespective of the electrical length of the coupling region. When combining the two quarter wavelength sections, the feed is therefore analogous to a single directional coupler with one open end connected to the SMA connector for input power, whereas the second open end terminates in a load (the proposed resonator). The fringing capacitances at the open circuit end as well as at the transitions in line width will have to be dealt with by an appropriate reduction in the line lengths.

$$P = \left|2k^2 - 1^2\right|^2 + \left|2jk\left(1-k^2\right)^{0.5}\right|^2 \qquad (1)$$

The respective powers at each port are tabulated in Table 1 using the equations available in [3]. Adding the powers of Table 1 gives the systemic power output stated in Eq. (1). Fig. 3(a) depicts the coupling coefficient (k) vs coupling space (δ), whereas Fig. 3(b) shows the voltage standing wave ratio (VSWR) vs k and that $k = (Z_{0e} - Z_{0o})/(Z_{0e} + Z_{0o})$ where Z_{0e}, Z_{0o} are the even and odd charateristic impedances respectively of the proposed capacitively coupled feed line. Eq. (8) of [6] explains the relationship between k and the odd/even characteristic impedance function of the parallel-coupled sections. At $k = 0.71$ (3 dB), P = 1. The total output power is equal to the input power. By implication, there is no reflected power at the original input port, indicating a good impedance match and that all the power is coupled through the structure to port 6. At $k = 0.5$, $\delta = 0.3$, whereas VSWR = 1.85 mm. As δ increases, k decreases, and VSWR appreciates. Unfortunately, this progression cannot be sustained owing to litographic ecthing limitation.

III. Results and Discussions

A proof-of-concept rectangular patch antenna is designed using HFSS, and photo-etched on Roger duroid 4003C laminate board. The reflection coefficient ($|S_{11}|$) result is shown in Fig. 4. The proposed feed demonstrates a frequency pattern of 5.97 – 5.62 GHz against the inset coupled with a pattern of 5.82 – 5.78 GHz. The $|S_{11}|$ of the proposed feed is -24 dB whereas that of the inset feed is -21 dB.



The reflection coefficient ($|S_{11}|$) against resonance frequency

IV. Conclusions

The proposed feed demonstrated substantial bandwidth enhancement owing to reduced ohmic and parasitic losses along the feed line. The feed was also analyzed to determine the optimum coupling coefficient requisite to yield a low impedance match with respect to the maximum capacitance contribution in view of the possibility of an enhanced frequency pattern.

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