Tuneable and Dual-Band Circular Microstrip Antenna with Stubs

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***Abstract*—A circular microstrip antenna loaded along its feed axis with either one stub or two stubs has been analyzed using improved linear transmission line model. When the length of the stub is small, the frequency is tuned over 9% range in L-band and, when it is comparable to $\lambda/4$, it exhibits dual-frequency operation. The experimental results are in good agreement with the theoretical results.**

***Index Terms*—Dual-band, microstrip antennas, tuneable.**

I. Introduction

A RECTANGULAR microstrip antenna (RMSA) loaded along its feed axis with two stubs of small length, one each on the either side, has been reported [1]. By trimming the stub length, both the resonant frequency and the impedance have been very precisely controlled. A RMSA with a single stub of length $\lambda/2$ shorted at one end [2] or $\lambda/4$ with open-end [3] yields dual-frequency operation. Similarly, RMSA with two equal and unequal stubs yield dual- and triple-frequency operations [3]. A circular microstrip antenna (CMSA) loaded with two equal angular stubs have been reported to yield dual frequency [4].

In this paper, new configurations are proposed in which by placing single or double stubs along the feed axis of CMSA, frequency tuning and dual-band operations have been obtained. When the length of the stub(s) is small, then by changing its length and width, the resonant frequency of the CMSA is tuned. When the length of the stub(s) is comparable to $\lambda/4$, it yielded dual-frequency operation. The improved linear transmission line model has been reported for analyzing RMSA and CMSA [5]. This method has been extended to analyze the proposed antenna followed by experimental verifications.

II. Single Stub CMSA (SSCMSA)

A CMSA with a stub of length l_1 placed along the feed axis is shown in Fig. 1. The dimensions of the antenna for operation in the L-band were chosen as: radius $r = 3$ cm; feed point $x = 0.95$ cm; and stub width $= 0.4$ cm. The width of the stub has been kept small so that the radiation from it is negligible. The substrate parameters are thickness $h = 0.16$ cm, $\varepsilon_r = 2.33$, and $\tan\delta = 0.001$. As the stub length increases from 0.0 to 2.2 cm, the measured resonant frequency decreased from 1.868 to 1.695 GHz (theoretical: 1.866 to 1.700 GHz), and the measured input impedance decreased from 53 to 30 Ω (theoretical: 52.5 to 28 Ω), thereby reducing the bandwidth for VSWR ≤ 2 from 29 to 9 MHz (theoretical: 28 to 8 MHz). The effect of increase in the stub length is similar to that of increasing the effective area, which reduces the resonant frequency. With increase in the stub length, the effective center of the antenna shifts toward the feedpoint from the physical center of the CMSA and hence the impedance decreases. This yields a tuning range of about 9% with input VSWR less than two. For larger stub length, the impedance matching can be obtained by shifting the feed point toward the edge, which will also improve the bandwidth. The effect of changing the stub width on tuning the resonant frequency was also studied. As the width of the stub increases, the resonant frequency decreases with a small reduction in the input impedance.

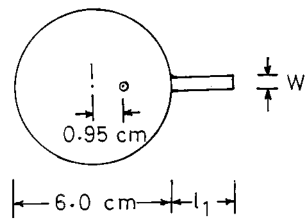

Fig. 1. Single stub loaded circular microstrip antenna (SSCMSA)

Dual-band operation is achieved when the stub length is comparable to $\lambda/4$. At the lower frequency, the stub presents a capacitive load, whereas at the higher frequency, it presents an inductive load. The theoretical and experimental dual-band resonant frequencies (f_1 and f_2) and their ratios for different stub lengths are shown in Table I. As the stub length decreases from 3.40 to 1.60 cm, the ratio of the two measured frequencies increases from 1.35 to 1.53. For the stub length $l_1 = 1.85$ cm, the theoretical and the experimental input impedance loci and VSWR plots are shown in Fig. 2(a) and (b), which are in good agreement. The measured bandwidths at f_1 and f_2 are 17 and 19 MHz, respectively.

III. Double Stub CMSA (DSCMSA)

The SSCMSA gives tunability as well as dual-band frequency response, but one of the main disadvantage is that the same feed point as that of the CMSA does not give good impedance match for larger stub length. It needs to be moved away from the center to get good match for the longer stubs. A CMSA with two stubs, shown in Fig. 3, overcomes this problem. As the stub lengths l_1 and l_2 increased from (0, 0) to (1.45 cm, 1.45 cm), the measured resonant frequency decreased from 1.868 to 1.721 GHz, the bandwidth decreased from 29 to 19 MHz, whereas the input

Manuscript received January 22, 1999; revised April 24, 2000.

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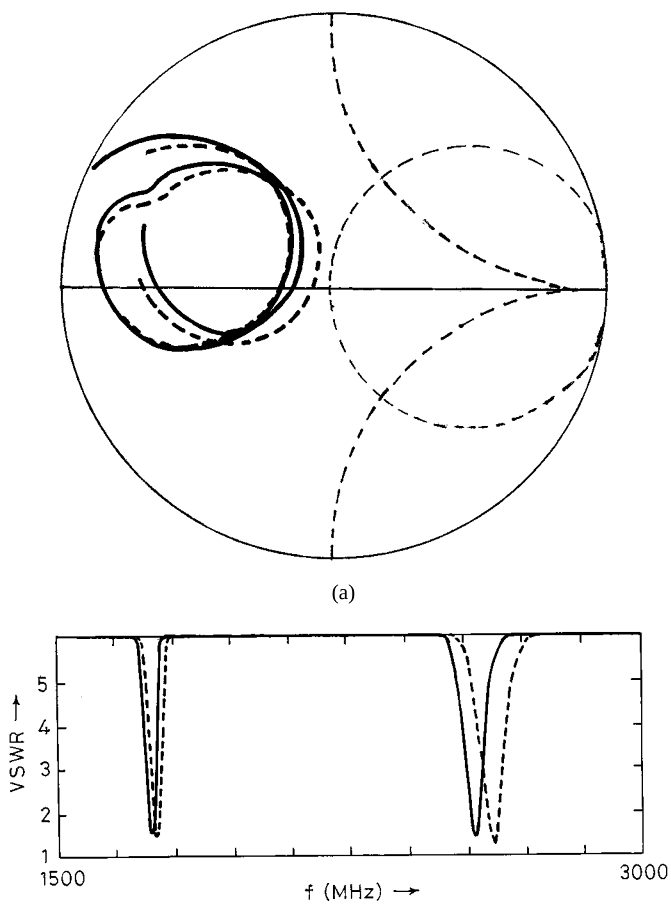
Publisher Item Identifier S 0018-926X(00)06932-5.

TABLE I
THEORETICAL AND EXPERIMENTAL DUAL-BAND FREQUENCIES OF SSCMSA FOR VARIOUS STUB LENGTHS AND MEASURED DIP IN THE BROADSIDE DIRECTION AT f_2

Stub length		f_1		f_2		Measured	Measured dip
l_1	l_2	Theor.	Exp.	Theor.	Exp.	f_2/f_1	in broadside
cm	cm	GHz	GHz	GHz	GHz		dB
2.55	1.50	1.590	1.582	2.190	2.142	1.354	0.0
2.55	1.20	1.600	1.590	2.210	2.168	1.363	0.0
2.25	1.00	1.660	1.647	2.385	2.294	1.393	1.8
2.00	1.00	1.695	1.685	2.465	2.431	1.443	6.0
2.00	0.50	1.715	1.705	2.565	2.468	1.448	7.0
2.25	2.25	1.585	1.598	2.591	2.583	1.616	13.5
1.75	2.00	1.660	1.679	2.950	2.935	1.748	11.0
1.65	1.75	1.678	1.685	2.982	2.973	1.764	5.0



(a)

(b)

Fig. 2. Input impedance and VSWR plots of a SSCMSA for $l_1 = 1.85$ cm - - - theoretical — experimental.

impedance decreased slightly from 53 to 50 Ω. The change in the impedance was more when the two stub lengths are unequal.

When the lengths of the either of the two stubs are comparable to $\lambda/4$, dual-band operation is achieved. By altering the individual stub length, the two frequencies are varied. Table II

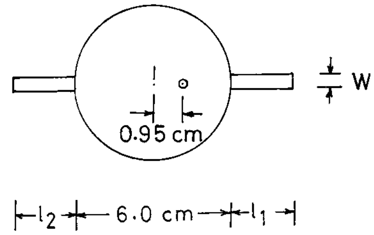


Fig. 3. Double stub loaded circular microstrip antenna (DSCMSA)

TABLE II
THEORETICAL AND EXPERIMENTAL DUAL-BAND FREQUENCIES OF DSCMSA FOR VARIOUS STUB LENGTHS AND MEASURED DIP IN THE BROADSIDE DIRECTION AT f_2

Stub length		f_1		f_2		Measured	Measured dip
l_1	l_2	Theor.	Exp.	Theor.	Exp.	f_2/f_1	in broadside
cm	cm	GHz	GHz	GHz	GHz		dB
2.55	1.50	1.590	1.582	2.190	2.142	1.354	0.0
2.55	1.20	1.600	1.590	2.210	2.168	1.363	0.0
2.25	1.00	1.660	1.647	2.385	2.294	1.393	1.8
2.00	1.00	1.695	1.685	2.465	2.431	1.443	6.0
2.00	0.50	1.715	1.705	2.565	2.468	1.448	7.0
2.25	2.25	1.585	1.598	2.591	2.583	1.616	13.5
1.75	2.00	1.660	1.679	2.950	2.935	1.748	11.0
1.65	1.75	1.678	1.685	2.982	2.973	1.764	5.0

gives the comparison between the theoretical and the experimental dual-band resonant frequencies (f_1 and f_2) and their ratios for various stub lengths. The decrease in the first resonant frequency is less as compared to the second frequency, when the stub lengths are increased. The theoretical and the measured impedance and VSWR curves for stub lengths $l_1 = 1.75$ cm and $l_2 = 2.0$ cm, shown in Fig. 4(a) and (b), are in good agreement. The measured bandwidths at f_1 and f_2 are 20 and 18 MHz, respectively.

IV. RADIATION PATTERN

The measured radiation patterns for all the tuneable cases have beam maxima in the broadside direction and the cross-polar levels are 20 dB below the copolar levels. These patterns are similar to that of the CMSA. In all the dual-band operation, the radiation patterns are in the broadside direction at the lower resonant frequency, whereas for some cases, there is a dip in the broadside direction in the E-plane at the higher resonant frequency. The variations of the dip in the E-plane for both SSCMSA and DSCMSA are also given in Tables I and II, respectively. It is noted that as the ratio of the two frequencies approaches 1.658 (ratio of the first two roots of the derivative of the Bessel function 3.0542/1.841 18), the dip in the broadside becomes more pronounced. It indicates that the second resonance is moving toward the higher order mode, which has the conical pattern. It is also observed from Table II that when the

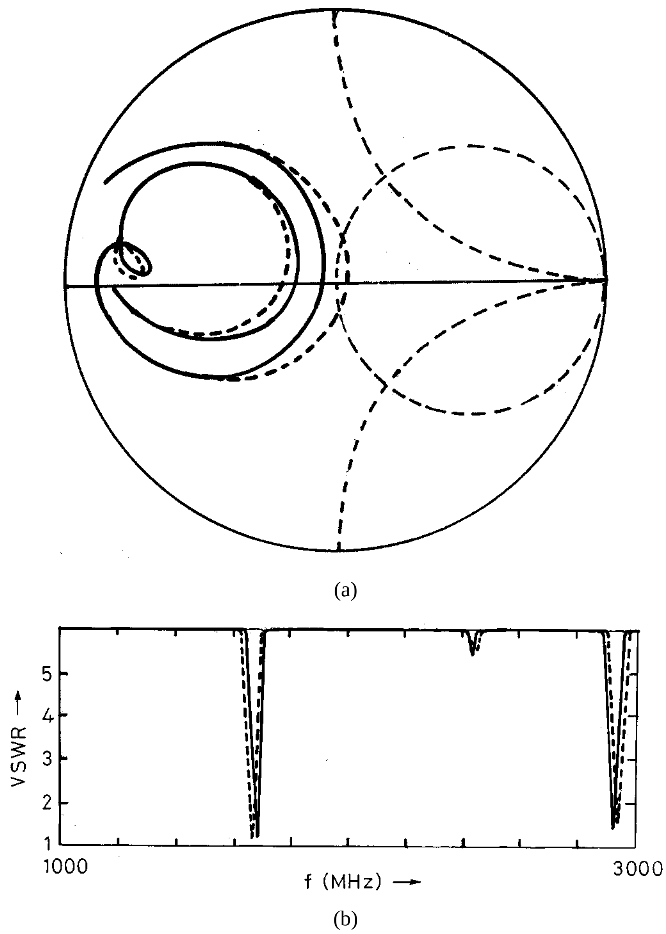


Fig. 4. Input impedance and VSWR plots of a DSCMSA for $l_1 = 1.75$ cm and $l_2 = 2.0$ cm - - - theoretical — experimental.

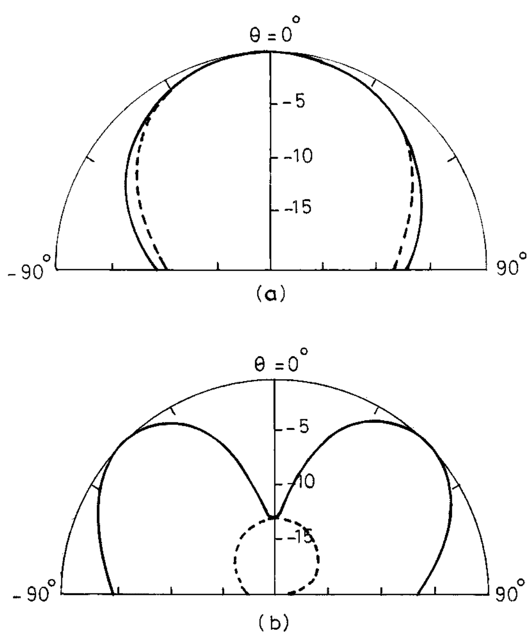


Fig. 5. Measured radiation pattern of dual-band DSCMSA for $l_1 = l_2 = 2.25$ cm at (a) $f_1 = 1.598$ GHz and (b) $f_2 = 2.583$ GHz — E-plane, - - - H-plane

length of the two stubs are nearly equal, the ratios between the two frequencies are close to 1.658 and, hence, there is a larger

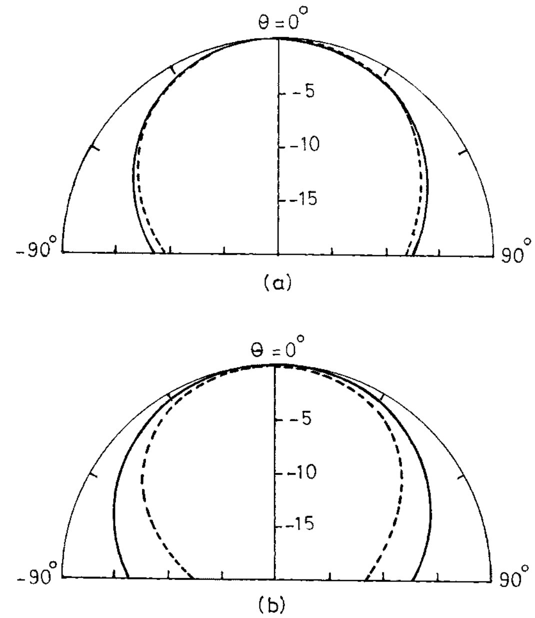


Fig. 6. Measured radiation pattern of dual-band DSCMSA for $l_1 = 2.55$ cm, $l_2 = 1.5$ cm at (a) $f_1 = 1.582$ GHz and (b) $f_2 = 2.142$ GHz — E-plane, - - - H-plane.

dip in the broadside at f_2. For DSCMSA with $l_1 = l_2 = 2.25$ cm, the measured radiation pattern at two frequencies is shown in Fig. 5(a) and (b). The radiation is in broadside at f_1 and conical at f_2.

When the two stub lengths are very different, then the ratio of the two frequencies shifts away from 1.658 and, therefore, the dip reduces or disappears in the broadside at the second resonant frequency. This can be clearly seen from the measured radiation pattern shown at the two resonant frequencies in Fig. 6 for $l_1 = 2.55$ cm and $l_2 = 1.5$ cm for which $f_2/f_1 = 1.354$. The pattern has maximum radiation in the broadside direction at both the frequencies.

V. Conclusion

Two configurations of single stub and double stubs loaded CMSA have been proposed for the tuneable and dual-band operations. The theoretical results obtained using the improved linear transmission line model are in good agreement with the experimental results.

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