Design and Fabrication of Triple Frequency Microstrip Patch Antenna by Attaching Tuning Stub Element

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***Abstract*—This effort aims to design and fabricate a triple frequency rectangular patch antenna, by attaching a single stub element of a varying length (rectangular-shaped), to the top left corner of radiating edge of the patch, to act as a tuning network. The patch and the stub are excited through a 50 Ohms insert-fed line, connected to a midpoint of the patch. The whole structure is embedded on a single FR4_epoxy substrate. Methodology of this work is based on trial and error. Behavior of proposed prototype antenna was discussed in terms of three simulated and measured analytical parameters, return loss, Voltage Standing Wave Ratio and input impedance of the patch. Three measured resonant frequencies are 4.71 GHz (C band), 10.6 GHz (X band) and 11.85 GHz (X band) were achieved for 7 mm stub length. HFSS13.0 was used as a software tool.**

Keywords—rectangular patch antenna; return loss; *VSWR;* ***patch input impedance; dual and triple frequency antennas***

I. Introduction

Due to recent developments in mobile and wireless communication industry, urgent demand for wireless connectivity necessitates use of a single antenna to cover multiple frequencies.

One simple way to cover several frequencies is by using wideband antennas, but additional band pass filters are needed to prevent or minimize interference with other existing wireless systems while servicing within same geographical area [1], [2].

Operation over narrow triple frequencies with just a single patch antenna is very useful, especially when the antenna has similar gain, directivity, radiation patterns, polarizations, input impedance and other technical characteristics over each frequency [2]–[4].

When an antenna operates only at three spot frequencies, it is called a triple frequency antenna, but when it operates over a finite triple bandwidths comprise those triple frequencies, it is called then triple band antenna [5], [6].

Operation over two or more discrete frequencies is desired for many applications, such as Synthetic Aperture Radar (SAR), Global Positioning System (GPS), Wireless Local Area Networks (WLANs) and so on [7]–[9].

If two frequencies are far apart, a dual-frequency antenna should be used to avoid the use of two separate antennas, or if two or more frequencies of an antenna are adjacent to each other, a dual or triple band antenna is needed. However, the major challenge for designing a triple band antenna is that the ratio of center frequency between each successive band should be a minimum of 1.6 for better frequency rejection and less interference between the frequency bands [9], [10].

There are two different methods widely used for patch antennas tuning. One is to insert a separate tuning network without altering or deforming the radiating patch structure. The advantage of that is the patch does not need not to be changed, but the antenna size will be increased [8], [9].

Another method is by inserting of an on-patch tuning network; connecting a variable reactive (inductive or capacitive) load to the patch. Selecting proper length of a

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small stub attached to regularly shaped microstrip antennas, by slotting or notching the radiating patch top surface, by changing the number of shorting posts, by using either slot or shorting pins. That can transfer the higher input impedance at the patch edges to the lower 50 Ohms characteristic impedance of the feeding structure. That simplifies the design process and does not increase the patch size [11].

A. Tuning Stub Element

Geometry of proposed rectangular patch antenna with a single stub is shown in Fig-1. A parametric study was performed to obtain three resonant frequencies versus a specific length of the stub. In order to tune the antenna, the stub of varying length and fixed width is physically connected to the top left corner of radiating edge of the patch, whose dimensions in millimeters are tabulated in table I.

TABLE I. PATCH AND STUB DIMENTIONS

Patch Width	Patch Length	Stub Width	Stub Length
29.44	38.04	3.4	Variable

Fixed dimensions in millimeters of FR4_eboxy substrate are tabulated in table II.

TABLE II. SUBSTRATE DIMENSTIONS

Substrate Width	Substrate Length	Substrate Height	Permittivity
29.44	38.04	1.6	4.4

Then, increasing the length of the stub along the patch length on 1 mm step-size basis, from 1 mm to 38.4 mm (38.04 mm is the total length of the patch) and observing frequency response of the antenna parameters in return of S_{11}, VSWR and Z_{in}. Other antenna parameters remained unchanged.

Fig. 1. A fabricated rectangular patch antenna with a stub

II. RESULTS AND DISCUSSION

The three analytical parameters, S_{11}, VSWR and Z_{in} were observed and compared for both HFSS simulation results and laboratory measurement.

The return loss (S_{11}) was simulated for the proposed patch antenna over a frequency range from (0 to 15 GHz). As seen in Fig. 2, the best results were achieved at different frequencies corresponding to the return loss magnitudes which are below -10 dB. The lowest return loss magnitudes are 17.3 dB, -20.02 dB and -28.07 dB. They satisfy standard antenna return loss criteria for any particular operating frequency, which defines that acceptable return loss for proper antenna performance must be less than -10 dB.

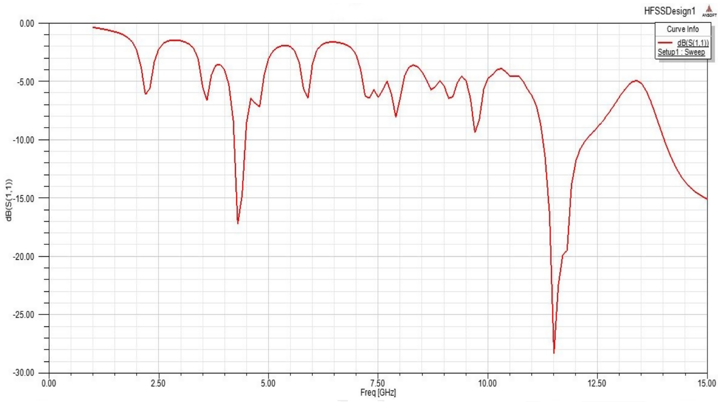

Fig. 2. Return loss versus frequency (simulated)

The Voltage Standing Wave Ratio (VSWR) was simulated for the proposed patch antenna over the same frequency range from (0 to 15 GHz), as seen in Fig. 3. The best results were achieved at different frequencies corresponding to the VSWR magnitudes which are confined between 1 and 2. The acceptable obtained VSWR magnitudes are 1.6, 1.6 and 1.83. They meet standard antenna VSWR criteria for any particular operating frequency, which defines that acceptable VSWR for proper antenna performance must be confined between 1 and 2.

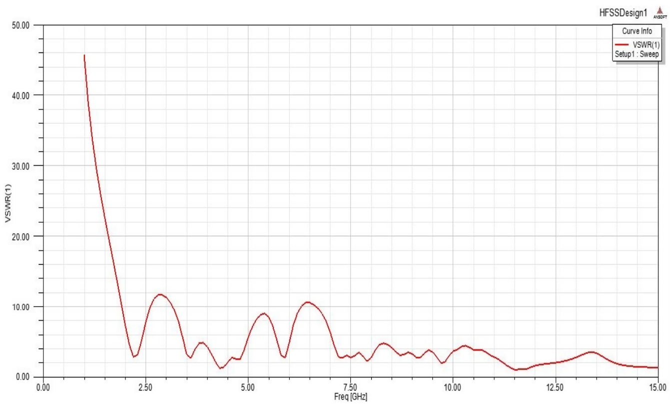

Fig. 3. VSWR versus frequency (simulated)

The input impedance of patch antenna was simulated for the proposed patch antenna over the same frequency range from (0 to 15 GHz), as seen in Fig. 4. The best results were achieved at different frequencies corresponding to 57 Ohms, 62 Ohms and 54 Ohms respectively. Theoretically, that shows good matching between patch input impedance and the feeder.

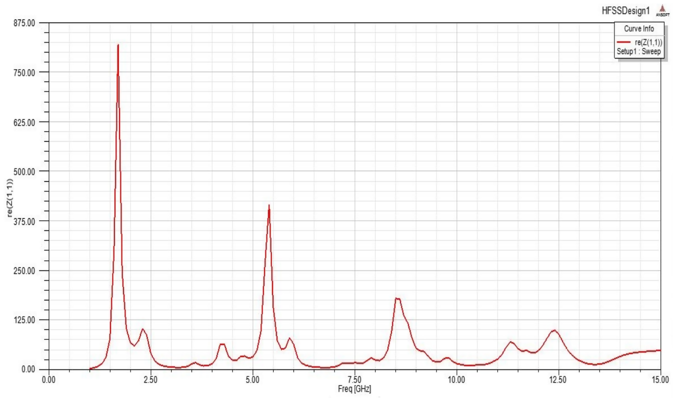

Fig. 4. Input impedance versus frequency (simulated)

The return loss (S_{11}) was measured in the laboratory for the fabricated patch antenna over the same frequency range from (0 to 15 GHz), as seen in Fig. 5. The best results were achieved at the triple frequencies; 4.71 GHz, 10.6 GHz and 11.85 GHz corresponding to return loss magnitudes; -21.94 dB, -14.07 dB and -21.57 dB respectively. These practical results comply with the standard antenna return loss criteria for the three mentioned frequencies.

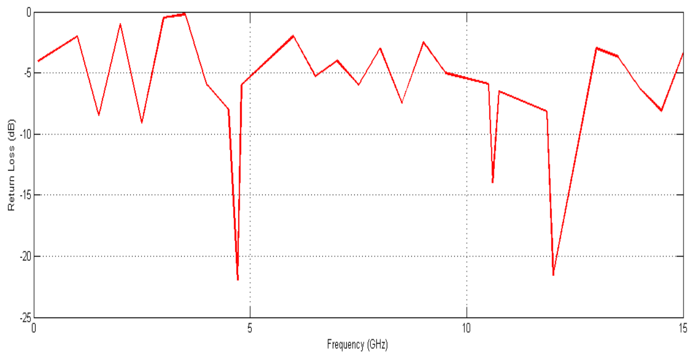

Fig. 5. Return loss versus frequency (measured)

The Voltage Standing Wave Ratio (VSWR) was measured in the laboratory for the fabricated patch antenna over the same frequency range from (0 to 15 GHz), as seen in Fig. 6. The best results were achieved at the same triple frequencies; 4.7 GHz, 10.6 GHz and 11.85 GHz corresponding to voltage ratios; 1.54, 1.51 and 1.76 respectively. These results comply with the standard antenna VSWR criteria, which defines that acceptable VSWR for proper antenna performance must range between 1and 2.

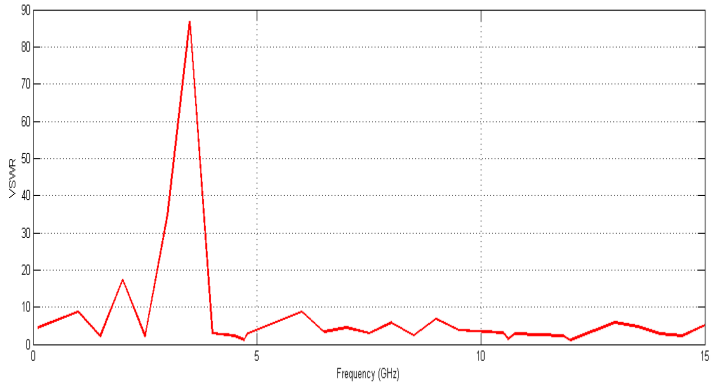

Fig. 6. VSWR versus frequency (measured)

The input impedance of patch antenna approaches to the 50-Ohms-feeder impedance. It was measured in the laboratory over the frequency range from (0 to 15 GHz), as seen in Fig. 7. Best results were achieved at the same the triple frequencies; 4.7 GHz, 10.6 GHz and 11.85 GHz corresponding to input impedance values; 58.6 Ohms, 66 Ohms and 58 Ohms respectively. The results show three good impedance matching conditions between the radiating patch and its feeder. Satisfactory antenna performance is guaranteed under these conditions.

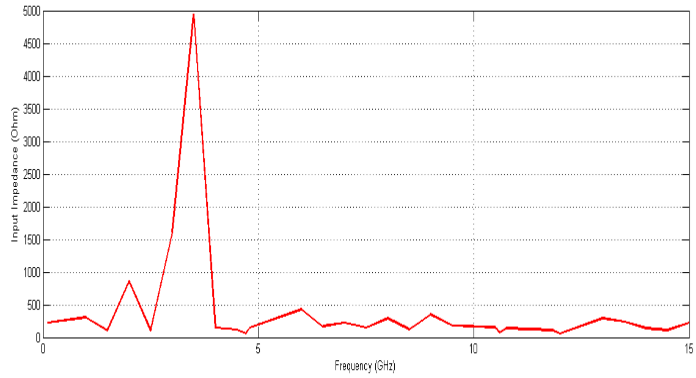

Fig. 7. Input impedance versus frequency (measured)

III. CONCLUSION

Triple frequency rectangular patch antenna tuned with stub was designed and fabricated. Resonance frequencies are 4.71 GHz, 10.6 GHz and 11.85 GHz, versus return loss magnitudes of -21.94 dB, -14.07 dB and -21.57 dB respectively, were achieved for 7 mm stub length. Measured VSWR and input impedance of the patch for those frequencies came within acceptable values. Those resonant frequencies are segments of both C and X bands. It is observed that the theoretical results differ a little bit from their corresponding experimental measurements. It is possible to achieve other single or dual frequencies versus other lengths of the stub. Resonance frequency and impedance matching depend literally on the stub length. The proposed antenna is suitable for applications such as Radar systems, military communications and terrestrial networks, as X-band frequencies are allocated to operate in Libya for those applications.

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