L / C / X Triple band compact dipole array antenna for RADAR application

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Abstract: This article describes about L / C / X triple band compact dipole array antenna for RADAR communication using FR-4 Substrate. The proposed antenna is designed over a range of 1.0–10.0 GHz. The objective of the paper is to achieve appreciable basic antenna parameters for ease adaptation in Monolithic Microwave Integrated Circuits (MMIC) Technology. It is able to preserve its high recital over RADAR Communication system operating at Triple band (L, C, X – band) microwave frequency range. The proposed structure resonates at L / C / X Microwave bands and thus the antenna becomes inevitability for numerous wireless applications. The antenna is fictitious on a substrate with height of 1.6 mm, length 48mm, width 60mm and a relative permittivity of 4.2. The proposed antenna yields a VSWR of about 1.74 (1.70 GHz), 1.66 (6.70 GHz), 1.26 (8.30 GHz) and gain of 2.56 dBi (1.70 GHZ), 1.78 dBi (6.70 GHz) and 3.94 dBi (8.30 GHz) under simulation. The antenna is designed and simulated using HFSS, which helps to obtain the antenna parameters such as VSWR, gain and Return loss.

Keywords: Array, HFSS, Gain, VSWR, Directive gain.

1. Introduction

In current years, the growth of wireless systems required low cost, compact size and low outline antennas that are able of achieving good recital over an extensive spectrum of frequencies. In progress the RADAR systems is to expand printed antennas at minimal cost and compact size which are proficient to preserve high recital over an extensive frequency spectrum. Due to low fabrication and compactness of the planar antennas, the field is attracting the researchers to work in this area. [¹-⁴] To maintain the compactness, operating in multiple frequency bands and achieving high gain of the antenna is still a challenge to the researchers. [²] Antenna is a significant device of any wireless communication system as it converts the electrical signals into Electromagnetic (EM) Waves professionally with low loss. An antenna is a device which radiates EM waves and vice versa. It is more often than not used with an EM transmitter or receiver. In transmission, EM supplies a current oscillating at EM frequency to the terminals, and it radiates the energy from the current (I) as EM waves. In reception, an antenna intercepts some of the power of an EM wave with the purpose of produce a small voltage at its terminals, which is given to a receiver to be amplified.

It is considered as indispensable components of all undertake that uses radio. They are used in systems such as broadcasting, radar, mobile and satellite applications, in addition to other devices such as garage door openers, microphones, Bluetooth-inbuilt devices and RFID tags on merchandise. It consists of a pact of metallic elements which are electrically associated to the receiver or transmitter.
An oscillating current of electrons obligatory in the course of the antenna by a transmitter will craft an oscillating magnetic field approximately the antenna elements, even as the charge of an electron also craft an oscillating electric field next to the elements. These time-varying fields radiate left from the antenna into space as a moving $T_{EM}$ field. \cite{12-16} The dipole is mostly utilized on its own through oscillating current, but it is also included into many other RF antenna designs where it forms the radiating or driven element for an antenna.

The dipole is an unpretentious to build and employ also several of the computation is reasonably uncomplicated. \cite{21} Though like all other antennas, the exhaustively calculations are significantly additionally complex. As the term proposes the dipole, it contains of two fatal or “poles” into which EM current flows. \cite{22} This current and the related voltage cause the EM signal to be radiated. As seen the antenna consists of a radiating part that is ripping normally in the middle to allow a feeder to give power to it from a transmitter or to acquire power from it to a receiver. The length determines a lot of property of the dipole from its impedance, center frequency etc. Together the V-I on the dipole fluctuate in a sinusoidal approach, import that there possibly will be other peaks and troughs imaginatively the span of the radiating sections dependent upon their extent. The extreme extensive form of dipole is the half wave and for this, the current is at least at the ends and rises to an utmost in the center where the feed is given. \cite{23}

Conversely the potential difference is low at the center and go up to extreme at the ends. It is usually fed at the middle, at the position where the current is at utmost and the amplitude a least value. This offer low impedance feed location which is opportune to feel. High magnitude feed location are far fewer opportune and hard to use. When a lot of half wavelength dipoles are used, they are likewise normally fed in the midpoint. At this juncture for a second time the potential difference is at a least amount and the current is at a maximum. Theoretically any of the current is at a maximum nodes can be used. \cite{23-25} The dipole is predominantly fundamental form of RF antenna which is very extensively second-hand for EM transmitting and receiving purpose. The important parameters of an antenna are impedance, broadband and return loss \cite{28}.

The L / S / C / X band described by an IEEE with frequencies and wavelength ranges varies 1.0 to 2.0 GHz, 30 to 15 cm and 2.0 to 4.0 GHz, 15 to 7.5 cm and 4.0 to 8.0 GHz, 7.5 to 3.75 cm and 8.0 to 12.0 GHz, 3.75 to 1.25 cm, respectively. The operating frequency can be forbidden by adjusting the size of an antenna. The L band is used for Navigation and surveillance radar. The S band is used for Terminal air traffic control, long-range weather and marine radar. The C band is used for Communication Satellite transponder and Precision Coherent Monopulse Tracking (PCMC) Radar. \cite{12-16} The X band is predominantly for missile tracking, Radar and satellite application. The rest of the paper is divided as follows. Section II System Model discusses the system model. Section III Design Consideration presents the design consideration of an antenna. Section IV explains the results and finally section V gives the conclusion.

2. **System Model**

The dipole has two radiating elements such as metal wires or rods, which are fed by a signal source or feed energy that has been selected up to a receiver. The energy may be transferred to and from the dipole either directly at once into the electronic instrument or it may be transferred some distance using a feeder. This leaves considerable opportunity for a multiplicity of diverse formats. Although it is frequently while in its format, there are yet a lot of forms of the antenna that can be use.

**Half wave dipole:** It is the one that is extensively used. Being $\lambda/2$ long it is a resonant aerial.
**Multiple half wave dipoles:** It is likely to exploit a dipole or aerial that is strange numerous of \( \lambda/2 \) long.

**Folded dipole:** As the name entail this is folded back on itself. Though stagnant in keep the length amongst the ends of \( \lambda/2 \), a further span of conductor efficiently attach the two ends together. It offers more radiation resistance because of folding set up in the structure.

**Short dipole:** A short dipole is one where the span is to an immense extent shorter than that of \( \lambda/2 \) long. Where a dipole is shorter than \( \lambda/2 \) long, the feed impedance starts to go up and its response is not as much of dependent upon frequency changes. Its span also turns out to be less significant and has a lot of return. It is found that the recent summary of an antenna is about a triangular distribution.

**Non-resonant dipole:** A dipole may be operated away from its resonant frequency and fed with an elevated impedance feeder. This facilitate it to work over a to a large extent wider bandwidth.

Improvements due to the use of alternate feed geometries, such as sequentially rotated feeding and sub arraying, are also quantified and are shown to be substantial. In the corporate feeding network, there is a complimentary identical path from the source to each of the radiating elements without passing through any other radiator. The favored models for the scrutiny of MSA are the transmission line model, cavity model, and full wave model. The transmission line model is the ease method of all and it provides superior corporeal just around the corner, but it is less precise. The cavity model is more precise and gives superior corporeal insight but complex in nature. The full wave models are awfully precise, adaptable and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. This wave model gives not as much of insight as compared to the two models mentioned above and is far more composite in nature. The feeding is the important consideration for energizing the antenna. Among center, coaxial and patch feed, the patch feed is proposed in the antenna structure shown in figure 2. Patch feed has easy fabrication and easy impedance matching. Also feed radiation and reliability is better in Patch feed.

3. **Antenna Design**

There are some parameters that affect the antenna performance. Two noticeable parameters that establish the recital of the antenna are width \((W)\) and length \((L)\) of the dimension. The return losses vary according to the parameter changes. A tradeoff bond exists between aerial dimension and bandwidth. Generally, the connection of width, height and relative permittivity of substrate are related as in Equation (1)

\[
\varepsilon_{\text{eff}} = \left(\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\right) \ast \left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}}
\]  

The proposed antenna structure can be designed using the following equations. The height and width of the dielectric substrate are given in Equations (2) and (3) as follows:

\[
h \geq \frac{0.06\lambda}{\sqrt{\varepsilon_r}}
\]

\[
w = \frac{C}{2f_0 \sqrt{\frac{2}{(\varepsilon_r + 1)}}}
\]
The actual length (L) of patch can be obtained by the following Equation (4)

\[ L = L_{\text{eff}} - 2\Delta L \]  \hspace{1cm} (4)

Where,

\[ f_0 = 6.6 \text{ GHz} \]

\[ \varepsilon_r = 4.2 \ (FR - 4) \ & \ h = 1.6\text{mm} \]

\[ \lambda = \frac{c}{f_0} = 0.045\text{m} \]

Figure 1. Design flow graph of an antenna

The dimension of proposed antenna is given in Table 1 and structure given in figure 2 and the design flow diagram as shown in figure 1.

Figure 2. Dipole array Antenna (2D)
The physical parameters are calculated by using equation (1 – 4) and it is tabulated in table 1 as given below.

**Table 1. Physical Parameter of Antenna**

| S. No | Description                        | Value            |
|-------|------------------------------------|------------------|
| 1     | Patch dimension (L×W)              | 48 mm × 60mm     |
| 2     | Feed width                         | 2 mm             |
| 3     | Substrate Material                 | FR 4             |
| 4     | Dielectric loss tangent (ταδ)      | 0.0001           |
| 5     | Thickness (h)                      | 1.6 mm           |

### 4. Antenna Simulation

Antenna parameters like VSWR, Return loss and gain has been intended and pretend for the proposed antenna with three different frequencies. VSWR value specifies how well the antenna is transmitting the signals. It gives a positive number that describes the impedance matching of an antenna \(^{[27-29]}\). In practical, the VSWR should be between 1 and 2 for less reflection losses. Return loss (S\(_{11}\)) gives the total loss of power in the signal transmission. The antenna will work in efficiently, if the return loss is low. Gain of an antenna represents the efficient conversion of input power into EM waves. The following formulas (equation 5, 6, 7) are used to calculate the VSWR, Return loss and Gain.

\[
VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \quad (5)
\]

\[
RL(dB) = 10\log_{10} \frac{P_i}{P_r} \quad (6)
\]

\[
G = \frac{P_o}{P_{in}} \ast D \quad (7)
\]

Where, D- Directivity in dB, G – Gain in dB

Return loss states that the practical circuit realization experience with the mismatch between the available source power and the power delivered. Return loss -20log (\(\Gamma_{in}\)) of the antenna is obtained as 1.70 GHz at -11.79 dBi, 6.70 GHz at -12.93 dBi, 8.30 GHz at -18.90 dBi. So, the designed antenna offers good gain and minimum losses at the specified frequency. Figure 3 illustrates the reflection coefficient of the MSA, obtained with help of HFSS software. The antenna is resonating at three frequencies 1.70, 6.70 and 8.30 GHz. The proposed antenna can cover all mobile frequency bands with constraint of VSWR as shown in figure 4. The results are shown in graph in Figure 5 with respect to frequency (X axis) versus VSWR, Return loss and gain (Y axis).
Figure 3. Return Loss Vs Frequency

Figure 4. VSWR Vs Frequency

Figure 5. Gain Vs Frequency
The gain and directivity of an antenna is obtained and given in figure 6 & 7. The obtained values of a proposed compact dipole array antenna have been listed in Table 2.

Table 2. Comparative Analysis

| Proposed Antenna Results | Paper [13] |
|--------------------------|------------|
| Frequency                | 1.7 6.7 8.3| 9.54 12.9 |
| VSWR                     | 1.74 1.66 1.26 | - - |
| S11                      | 1.79 12.93 18.90 | 20.51 28.13 |
| Gain                     | 2.56 1.78 3.94 | 3.98 1.14 |

Table 2 shows the comparative analysis, the results are very nexus but the proposed compact dipole array antenna achieves appreciable gain compared to paper [13]. The proposed dipole array antenna resonates in the low frequency range (1 - 10GHz). In the low frequency it is very difficult to achieve the gain in the range of 3dBi due to impedance mismatch. The proposed antenna achieves gain nexus to 4dBi. Hence the proposed antenna covers L / C / X triple microwave frequency band and it is well suitable for RADAR application.
5. Conclusion

The present work has been successfully simulated. The proposed compact dipole array antenna exactly resonates at L / C / X triple microwave frequency band which was especially used for RADAR application. The lack of quality coverage in the environment creates need of antenna. To achieve this target, higher bands are preferable. The proposed antenna meets the current scenario and it is proved by the parameters obtained. In future to achieve better result, select a substrate with minimum $\varepsilon$ and implement a slot (or) slit integrated with metamaterial to get appreciable gain, directivity and efficiency.

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