DESIGN AND IMPLEMENTATION OF CROSS DIPOLE ANTENNA USING CST STUDIO SUITE

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Abstract:-

The cross-dipole antenna, also known as the crossed dipole or turnstile antenna, is a type of radio antenna widely used in applications requiring circular polarization and omnidirectional radiation patterns in azimuth plane and it improves axial ratio performance, making it suitable for telemetry and satellite downlink applications. the two dipole antennas mounted at right angles (90 degrees) to each other and typically fed with a 90-degree phase shift to produce circular or elliptical polarization. This setup improves the reception and transmission of signals, especially for satellite communications, aerospace systems, and telemetry applications, where the signal's orientation may differ. In this paper, the design concept, radiation pattern, impedance characteristics and practical implementation of the cross-dipole antenna are investigated. The antenna performance is verified through simulations and experiments in different frequency bands. In this cross-dipole antenna design, the frequency is centered around 1GHz to 5GHz in CST Studio Suite tool. The CST Tool analyses the key performance patterns like return loss, radiation pattern, gain and polarization characteristics through electromagnetic simulation. The results confirm that the designed antenna meets the requirements for space communication systems in the UHF band.[1]

Index Terms: *Cross Dipole Antenna Design, CST Studio Suite, Circular Polarization, Axial Ratio, Omnidirectional Radiation, UH Frequency Band, Electromagnetic Simulation, Satellite Communication, Return Loss.*

1. Introduction

In the case of modern wireless communication, antenna is the essential component that helps determine the effectiveness of the performance of signal transmission and reception. From different antennas available currently, one antenna that has received considerable attention because it is able to produce circular polarization and omnidirectional radiation pattern in the horizontal plane is the cross-dipole antenna.

The cross-dipole antenna produces the circularly polarized waves where there are two dipoles mounted perpendicularly with the difference in the phase shift being 90 degrees. Degradation of signal transmission is caused by polarization mismatch which is important when maintaining a link with a satellite in rotation, enhancing its resistance and improving signal quality.

This paper discusses a cross dipole antenna working in 1GHz to 5GHz UHF frequency band designed using CST studio suite. This software is a powerful 3D electromagnetic simulation tool. This design process involves parametric analysis and evaluation based on the antenna's properties such as VSWR, efficiency, polarization, gain, S Parameter, and Farfield.

2. Problem Statement

Cross Dipole Antenna is an advanced design of an antenna system which is an indispensable component of modern communication systems. This type of antenna includes two dipole antennas arranged perpendicular to each other in a horizontal plane. Such a signal will provide greater benefits in situations when the receiving antenna is not oriented at a constant angle. Polarization of antennas does not depend on the rotation of the receiving antenna but linearly polarized antennas need correct orientation both for a receiver and a transmitter. This feature is very important for navigation systems, satellite communication, radio astronomy, and mobile communication networks. This feature allows the emitted electromagnetic waves to rotate in space creating circular polarization. The antenna can create either RHCP (Right-hand circular polarization) or LHCP (Left-hand circular polarization) depending on the phase position. It is very important to reduce signal fading and minimize multipath interference in order to increase the reliability of the communication to control polarization in a complex environment. Baluns is used for balancing currents, reflectors – for directing radiation, and ground planes – for stabilizing antenna performance.

The receiver's orientation cannot always be controlled in practical communication systems, especially in satellite applications. For example, a satellite in orbit may change its orientation relative to Earth, but here the communication links must remain stable. The transmitted signal can be received effectively regardless of these variations that is ensured by circular polarization. This makes cross dipole antennas far more dynamic than traditional linear dipoles, when orientation diff which suffer from polarization mismatch losses. The effects of atmospheric disturbances such as faraday rotation helps to reduce the effect as they widely used in satellite communication, which alters the polarization of signals to pass through the design of cross dipole antenna using CST tool ionosphere. For example, in radio astronomy, cross dipole antennas are utilized to capture the polarized signals from celestial sources, to enable the properties of cosmic radiation. The other in navigation systems like Global Positioning System (GPS), it provides stable and accurate reception, which holds a main role in positioning and timing applications. Thirdly, In mobile and wireless communication systems, these antennas ensure proper consistent reception in handheld devices, where user orientation is unpredictable.

3. Working Principle

3.1 Flow Chart:

The fig 3.1 illustrates the systematic design and optimization process for a Dipole Antenna system. The first step of process begins by calculating the length of the dipole antenna. The second process is to determine the physical design of a dipole antenna which is operating at 1–5 GHz. Then the design is simulated using CST Studio Software to evaluate its performance. If the conditions of two critical Radio Frequency benchmarks - a VSWR of ≤2 and a Return Loss of ≤−10 dB are satisfied, the simulation checks for the antenna and the design is sent back through an optimization loop until the thresholds are met. Once the initial design passes, the designing process is advanced specially to make operate the double cross dipole antenna at 300MHz to 3GHz to undergo the same simulation and performance evaluation cycle and returns for optimizing if the criteria are not fulfilled. The antenna is physically fabricated after the both designs and its real-world performance is measured and validated against the simulated results. The conclusion of this workflow of the analysis are compiled into a report, then marking the completion of entire design process of the antenna. In the feedback-driven engineering workflow, before the physical prototyping it ensures that the antenna design is rigorously verified through simulation.

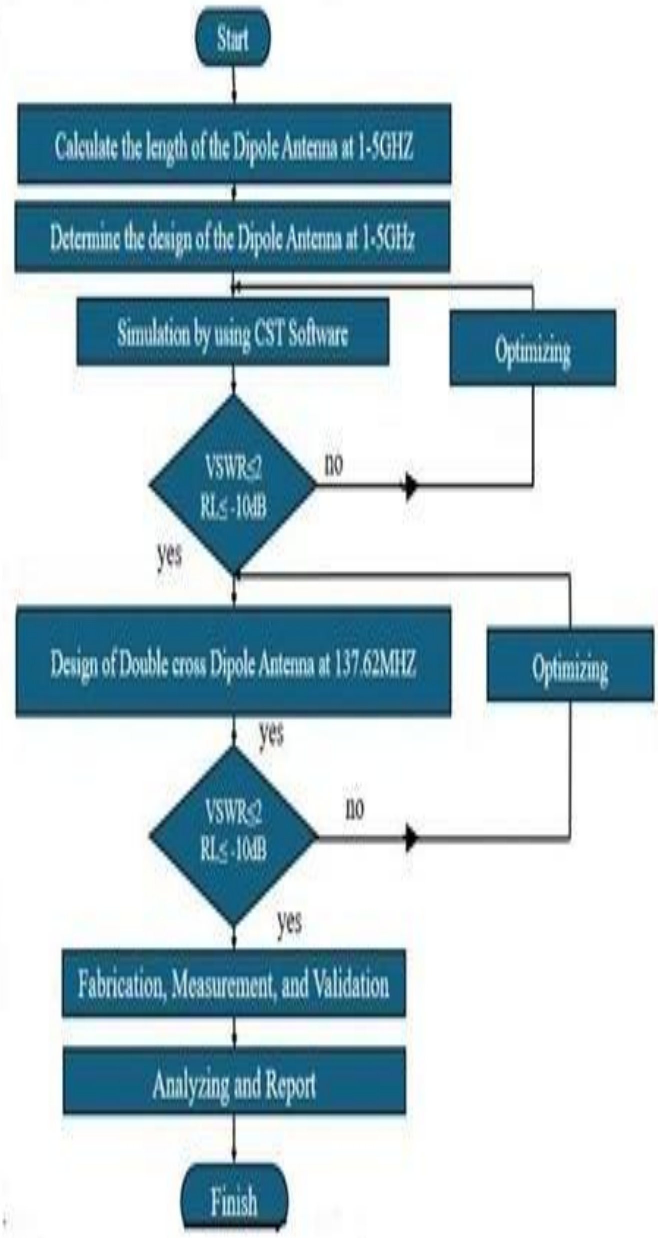

Fig 3.1 Flow chart of systematic design and optimization process for a Dipole Antenna system.

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4. Results

4.1 Different Parameters for 1GHz to 3GHz

4.1.1 S Parameters for 1GHz to 3GHz

The fig 4.1 shows the graph of S1.1 parameter (reflection coefficient) magnitude in dB vs frequency in GHz.

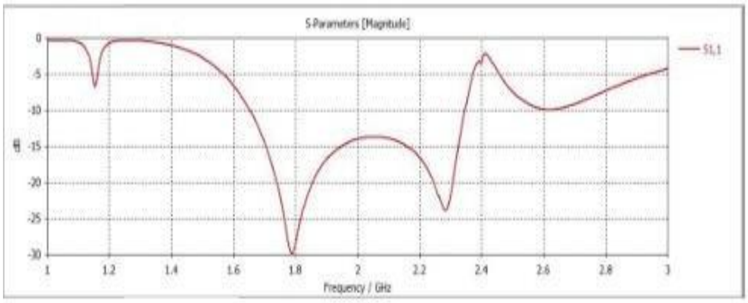

Fig 4.1: S-parameters (1GHz to 3GHz)

The S11 (return loss) graph is studied in the frequency range between 1 GHz and 3 GHz. Resonance is observed at around 1.2 GHz and 1.8 GHz, where there are notable dips in the S11 graph, thereby showing good impedance matching at these frequencies. It can be noted that the lowest value of return loss (of about -30 dB) occurs at 1.8 GHz, indicating very good impedance matching with very low reflection of energy. Thus, it can be concluded that the antenna performs well at these frequencies.

4.1.2 Power:

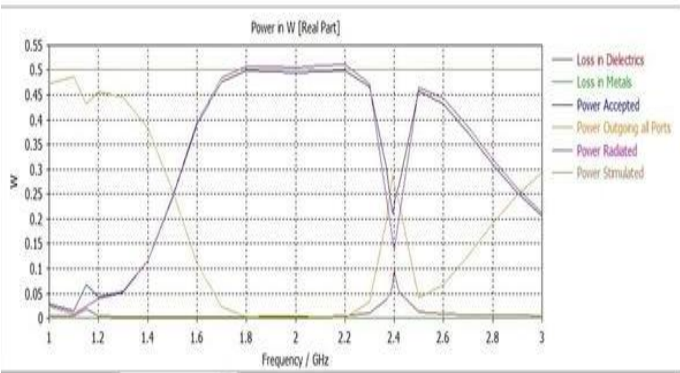

Fig 4.2: Power in W (min 1GHz to 3GHz)

Figure 4.2 illustrates the power distribution characteristics of the proposed antenna over the frequency range of 1–3 GHz.

Both average power and radiated power are fairly high between 1.7 GHz and 2.4 GHz, which means good power transfer and radiation in the operational frequency range. Also, it should be noted that losses associated with the dielectrics and metals are quite small for all considered frequencies, thus implying that there is almost no energy loss due to the material itself. Besides, it can be observed that the stimulated power falls with the rise in frequency, which is quite consistent with the input energy of the system.

4.1.3 Far Field Radiation:

The fig. 4.3 appears to be a far-field radiation pattern of an antenna, likely simulated using electromagnetic software.

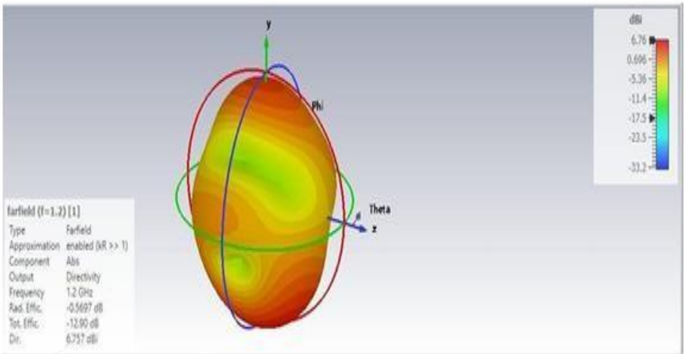

Fig 4.3: Far field Radiation (min 1GHz to 3GHz)

The 3D far field radiation pattern of the proposed antenna works at the frequency of 1.2 GHz. This demonstrates that the maximum directivity of the antenna is 6.757 dB. This verifies that the radiated power is efficiently directed to the desired direction. The radiation efficiency of the proposed antenna is determined as -0.5697 dB, which indicates that most of the accepted power is

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radiated by the antenna. However, the total efficiency of the antenna is computed as -12.90 dB. This reveals that there are losses in the radiated power.

4.2 Different Parameters for 2GHz to 4GHz:

4.2.1 S-Parameters

The fig 4.4 shows the S11 parameter (reflection coefficient) of a cross-dipole antenna simulated using CST (Computer Simulation Technology) software, with frequency ranging from 2 GHz to 4 GHz.

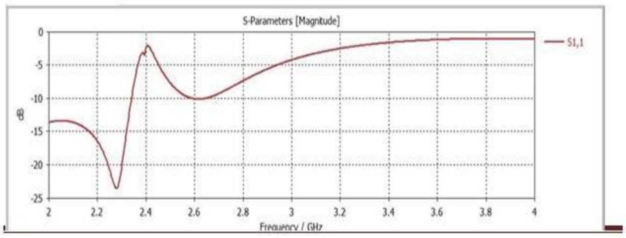

Fig 4.4: S-parameters (min 2GHz to max 4GHz)

The Directivity of the antenna is the maximum of 6.757 dB. This indicates good radiated energy concentration in one particular direction. The radiation efficiency of the antenna is calculated to be -0.5697 dB, which clearly indicates high energy transfer efficiency of the input power in terms of radiated energy. The overall efficiency of the antenna is -12.90 dB. This suggests the presence of some losses in the system because of impedance mismatching. The radiation pattern of the antenna is directional in nature.

4.2.2 Power:

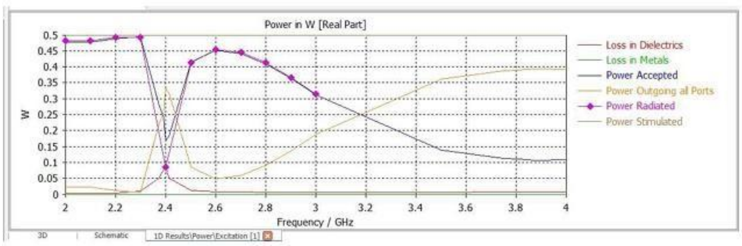

Fig 4.5: Power in W (min 2GHz to max 4GHz)

The fig. 4.5 shows power metrics vs frequency (2-4GHz) for an antenna or RF component.

Both the effective power and radiated power are high between the frequency range of 2.45 GHz and 2.7 GHz. It means that the antenna performs well in transferring and radiating power in the said frequency range. The losses in the dielectrics and metallic materials are constant in the entire frequency range; hence, the loss in the substrate and conductive materials is very low. Moreover, the stimulated (input) power decreases gradually with an increase in the frequency range due to the excitation of the antenna.

4.2.3 Far Field Radiation:

The fig 4.6 plot shows the Far Field radiation pattern of an antenna, likely simulated using electromagnetic software.

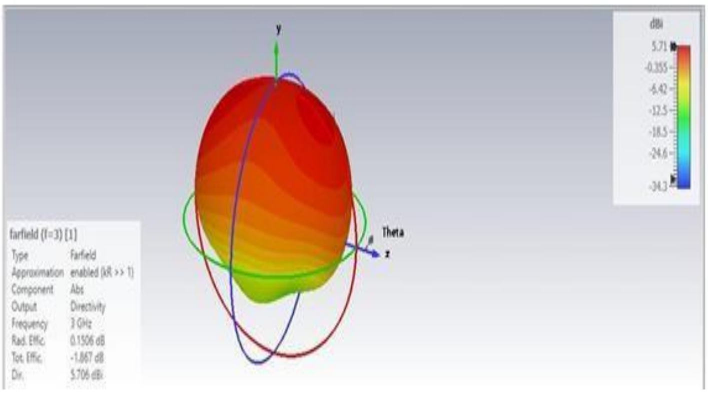

Fig 4.6: Far field Radiation (min 2GHz to max 4GHz)

The antennas directivity is highest at 5.706 dB. This means most of its energy is sent out in the lobe, which is shown in red. The main lobe is where the antenna radiates most of its energy. The antenna radiates 0.1506 dB efficiently. This shows that it uses most of its power well and doesn't lose much. The antennas overall efficiency is -1.867 dB. This means it doesn't lose any power due, to impedance or the materials used. The antennas

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efficiency is good. The main lobe of the antenna is the direction of radiation. The antennas main lobe is efficient.

4.2.4 VSWR:-

The fig 4.6 shows the Voltage Standing Wave Ratio (VSWR) of two configurations, VSWR1 (red) and VSWR2 (green), across a frequency range of 1 GHz to 3 GHz.

However, there is an obvious peak around 1-1.2 GHz and another one at 2.4 GHz on both graphs, showing that there are several frequencies of resonances. The graph of the VSWR2 setup reveals a higher peak on the lower frequency than that of the VSWR1 configuration. From 1.6 GHz to 2.2 GHz, both setups reveal almost unity VSWRs, showing that there is very good impedance matching and efficient power transfer between the antenna and the transmission line. After 2.6 GHz, the VSWR starts rising slowly, revealing poor impedance matching. Having multiple resonance points in the graph shows that the antenna is multiband in nature. Therefore, the proposed antenna will be useful in multiband wireless communication systems.

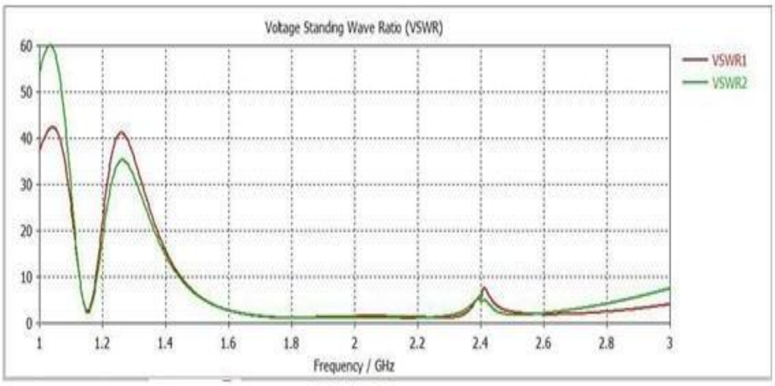

Fig 4.6: VSWR for frequencies (1-3GHz and 2-4GHz)

Table 4.1 Comparison of Antenna Performance Parameters

Parameter	**1–3 GHz**	**2–4 GHz**
Operating Frequency Range	1–3 GHz	2–4 GHz
Resonant Frequency	1.2 GHz, 1.8 GHz	Around 2.45–2.7 GHz
Minimum Return Loss (S11)	≈ −30 dB at 1.8 GHz	Good impedance match at operating range
Accepted Power	High between 1.7–2.4 GHz	High between 2.45–2.7 GHz
Radiated Power	High	High
Dielectric Loss	Negligible	Negligible
Metallic (Conductor) Loss	Negligible	Negligible
Maximum Directivity	6.757 dBi	5.706 dBi
Radiation Efficiency	−0.5697 dB	0.1506 dB
Total Efficiency	−12.90 dB	−1.867 dB
Radiation Pattern	Directional	Directional
VSWR	Close to 1 between 1.6–2.2 GHz	Good match around operating range

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Multiband Characteristics	Yes	Yes
Suitable Applications	Lower-frequency wireless systems	ISM band/WLAN/Wi-Fi/Bluetooth applications

5. CONCLUSION

Designing and Simulating Crossed Dipole Antennas in CST Studio Suite have brought forth the numerous benefits that arise from integrating the cutting-edge computing technologies into modern antenna design. Such antennas are employed extensively in satellite communications and global navigations systems to generate circular polarization that ensures the immunity of signals to any degradation resulting from the misalignment and multipath interference. With the help of CST Studio Suite, it becomes possible to accurately model the 3D structure of such antennas along with their orthogonal dipoles, feeding network, and phases. The software is capable of assigning realistic material characteristics and setting up boundary conditions and exciting with precise phase differences, thereby allowing the engineers to virtually test the performance of the antenna without having to rely on costly physical prototypes. Using this CST simulation, various important parameters like gain, return loss, input impedance, VSWR, radiation patterns and axial ratio can be accurately analyzed. In this way, the engineers will be able to determine that the antenna satisfies the requirements according to the desired operating range of frequency. The ability of using parametric sweeps and optimization in CST helps engineers in adjusting the design of an antenna in order to optimize different aspects such as dipole length, width, feed phase and others. Furthermore, the 3D visualization offered by CST is helpful in allowing designers to analyze the radiation pattern and polarization properties in detail that is necessary for ensuring reliable functioning in practice. The use of CST Studio Suite in the designing process of a cross-dipole antenna makes this process more effective, accurate and predictable and provides an engineer with a chance to create the optimal antenna design. The use of CST in the process of designing cross-dipole antennas proves its usefulness in connecting the theoretical analysis with the practical one. Using this software, the engineers will be able to simulate complex feeding structures, dual-layer reflectors or other modifications without the necessity of physical fabrication of many prototypes. It is for this reason that CST tools are able to offer high levels of performance when in use in the satellite communications industry, as well as circular polarization, which allows for in-depth study of frequency response, bandwidth, and axial ratio.

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