Studyof Crosseddipole Antennafor UHF SatelliteCommunication Applicationsand its limitations

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Abstract: *In the present day communication systems, especially for Submarine applications, a compact antenna is needed to communicate with Satellites. For communicating with Satellites, the compact antenna must have circular polarization characteristics, positive gain at ± 45° points of the main beam and the main beam position has to be in vertical direction. In this paper, the crossed dipole antenna is proposed, studied its characteristics and limitations for the ultra-high frequency Satellite Communication applications. Moreover the proposed antenna will be simulated and analyzed for various characteristics such as VSWR, Gain and Axial ratio and Radiation patterns at the downlink and uplink frequencies of the ultra-high frequency Satellite Communication applications.*

Index Terms:*Dipole Antenna, Crossed Dipole Antenna, UHF SatelliteCommunication.*

I. Introduction

A dipole antenna is most commonly a linear metallic wire or rod with a feed point at the entre. Dipole antennas and arrays of dipoles are commonly used for HF and UHF Communication, TV and FM broad casting and as electric field probes. The EM field radiated by antennas has both a magnitude and a direction

Drawbacks of theDipole antenna: Most of the energy radiated from dipole or bow – tie antennas is linearly polarized and oriented predominantly along the long axis of the antenna. A complete polarization mismatch using dipole antennas results when the scattered field and polarization of the receiving antennaare both linearly polarized and oriented at right angles to each other.

- The radiation resistance of an antenna that emits dipole radiation is proportional to the square of the peak (electric or magnetic) dipole moment of the antenna. This dipole moment is roughly the product of the peak charge times the length of the antenna in the case of a timer (electric) antenna and is the product of the peak current times the area of the antenna in the case of a loop (magnetic) antenna. Hence it is hard to increase the radiation resistance of small linear or loop antennas by altering their shapes.
- In the near zone the magnetic field B is in phase with the current in a simple small antenna, while the electric field E is in phase with the charge but the charge and current have a 90^0 phase difference. Hence they imply the electric and magnetic fields are 90^0 out of phase in the near zone, so that the radiation (which is proportional to EXB) is weak.

Crossed – dipole antenna:

The crossed – dipole antenna consists of transmit and receive antennas oriented orthogonal to each other and is sensitive to field components oriented parallel to the long axis of the receive antenna. So far many authors were studied and simulated the crossed dipole antenna for different applications. No one is simulated the crossed dipole antenna for UHF satellite communication application and analyzed the various characteristics like VSWR, Gain and axial ratio. The authors presented the characteristics, designs and applications of crossed dipole antenna [1] and they had discussed why dual – feed crossed dipoles have been installed in many broadband antennas. They said that the dual feed crossed dipole antennas can be designed to radiate isotropic, omnidirectional, unidirectional CP and unidirectional DP radiation. They described how CP radiation can be obtained with a single – feed structure by using the exact lengths of orthogonal dipoles. They also reviewed the recent including bandwidth enhancement, multiband operation and radiation central. They illustrated the different techniques to achieve multiple resonance and compact size. They also described compact radiators with different reflectors like cavity backed, AMC surface and planar metallic to achieve broadband and unidirectional radiation patterns. They discussed the importance of crossed dipole antenna [2] when it was used in high noise environments. The signal to noise ratio can be improved by using crossed dipole antenna. Reduction of cross- coupling of crossed dipole can produce cleaner images under suitable conditions and depending on the targets of interest. A method was proposed [3] to broaden the beam width of a crossed dipole antenna. By using four parasitic strips around the crossed dipole antenna, the beam widths were broadened effectively in the vertical plane over a wide frequency band. An L-band prototype (1.1GHz to 1.6GHz) crossed dipole antenna was fabricated and tested. The beam width at lower frequencies was broadened and uniform radiation patterns over the whole operating frequency band.A single feed wide band circularly polarized antenna was proposed for GNSS. The authors was used [4] the two orthogonal bowtie dipoles with double printed

quarters rings for getting matching with a antenna to a single 50 Ω co- axial line to produce CP radiation. The prototype antenna was designed and tested with an overall 1.2GHz frequency size of $0.48\lambda_0$x $0.48\lambda_0$x$0.25\lambda_0$.They had measured a value of $|S_{11}| <$-10dB band width of 1.05 – 1.79 GHz and also measured a3-dB bandwidth of 1.12 - 1.64GHz. Finally they got the RHCP with a small gain variation and high radiation efficiency (>93%) over the operational bandwidth. The wideband dual – polarized crossed – dipole antenna with the parasitical crossed strip [5] was presented and investigated. The parasitical crossed strips were used to achieve another resonant point and improved impedance band width. They had measured the values of 34.9% for $S_{11} \leq$ -10dB ($+45^0$ Polarization) and $S_{22} \leq$ -10dB (-45^0 Polarization). A compact [6] dual band antenna was presented for WLAN applications. This antenna consists of a dual band HIS and a cross – dipole. The simulated results of compact dual band indicates that gain of 3.8dBi at f_{low}= 2.4GHz and 6.3 dBi at f_{high}=5.4GHz in z-direction.A broadband printed cross – dipole element and feed network were designed [7] and fabricated to test four polarization re – configurations. The four polarizations are two linear and two circular in the operating band 1.7 – 2.5GHz. The broadband polarization reconfiguration were implemented using broadband $90^0/180^0$ phase shifters of switched network types. The fabricated BPCDE – PR showed the good performance in the operating band of about 40%.A dual band short backfire antenna was [8] developed based on the cross dipole excitation structure single impedance band width characteristics. The cross dipole excitation structure consists of H-shaped and straight cross dipoles. This cross dipole structure was mounted on the slotted co-axial time and developed on elliptical ground plane with dielectric arm. A cost effective design was obtained by using metallic rim from dielectric rim. They achieved the antenna characteristics such as VSWR bandwidth of 21% and 20.36% for 2:1 VSWR, axial ratio of 1.8dB with axial ratio (≤3dB) bandwidth of 1.94% and a gain of 12dBi. A novel circularly polarized antenna was [9] presented for broadband UHF Satellite Communication applications based on Moxon type antenna (bent dipole element over a ground plane). The broadband operation was achieved by using two vertical elements of the Moxon arms, widened strip arm element, bow tie arm structures with bents at 90^0. The presented antenna was fabricated and measured the results for the band of 225- 400MHz. the measured results are gain of 8-12dB, S_{11} is 10dB. An array of sequentially crossed dipole antenna [10] was designed to get excellent circular polarization and input impedance characteristics. A loaded crossed dipole antenna with broad – band omnidirectional horizontally polarized [11] was designed based on the two steps. First one was best omnidirectional pattern in the horizontal plane and second was antenna with the best performance was loaded with resonant tank circuits and   a matching network. Finally a QA was used to determine the load components, their locations and the parameters of the matching network.

Based on low profile cross – dipole and EBG/AMC structure, a new 8- port [12]interleaved base station antenna was designed. Three adaptive orthogonal crossed- dipoles [13] were used to remove the losses due to directivity and polarization mismatch if tracked by the transmit antenna. A GA quickly adapts the receive antenna to transmit antenna. Two antennas were designed [14] such as crossed meander antenna and crossed staircase antenna for RFID based sensor networks. Both antennas were designed to operate in the unlicensed 915MHz frequency band. A novel small size multi - band cross dipole antenna [15] was designed at the frequencies 0.543GHz, 2GHz and 6.5GHz based on a fractal first iteration quadraticand triangular Koch curve. The Method of Moments (MOM) techniques was used to calculated the current distribution along the cross fractal Koch curve antenna. A new compact dual polarization antenna was [16] designed at 2.23GHz and 5.14GHz. The dual polarized antenna consists of a rectangular patch with notches combined by a crossed dipole in the same ground and substrate by optimized of this new structure. The circularly polarized crossed Dipole Antenna was [17] designed based on the unequal length dipoles and two metal strips with phase delay lines for RFID hand held reader. They had measured the impedance bandwidth (VSWR ≤ 2) of about 11.8% and a 3-dB axial – ratio (AR) bandwidth of about 3.3% around the center frequency of 925MHz. The symmetric crossed – dipole FSR was [18] designed based on the frequency selection reflectarray for wireless communication applications. The FSR has the ability to function as a reflector and steer reflected beam for a special frequency band wave. The non – symmetric FSR using non – symmetric crossed dipoles antenna was also designed for dual – source and dual polarization operation with two main beams simultaneously. Moreover the FSR was implemented in a WCDNA system to eliminate the blind spots in Wireless Mobile Communications.

II. CROSSED DIPOLE MODEL

Dimensions:
Length: 62mm

Width: 8mm
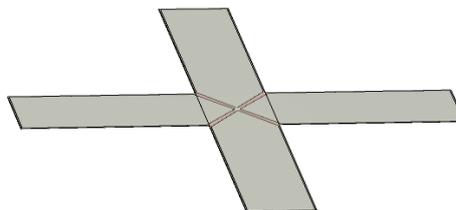
Fig. 1.Crossed dipole antenna.

In the crossed dipole antenna, two half wave dipoles placed at right angles to each other in the same plane, excited 90^0 out of phase with each other. The dipoles carry equal current in magnitude but in phase quadrature. The crossed – dipole arrangement is shown in fig.2 along with the directional pattern of individual and of the combination. Here two dipole patterns combining in the manner shown in figure, producing an almost circular pattern in the plane of crossed – dipole. The pattern also has the feature that it is polarized in the same plane. So that of it were mounted in the horizontal plane the antenna would radiate horizontally polarized wave about equally well in all directions along the ground.
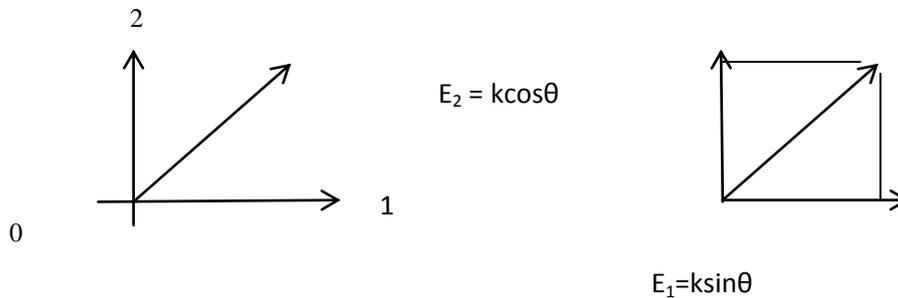
Fig.2 (a) plane view of Crossed diploe antenna Fig.2 (b) Vector diagram of field at a point P
Fig.2

Fig.2 (a) shows plan view of two short crossed dipoles. At a distant point P in the direction θ to the dipole no.1, the field magnitude due to dipole no.1 is proportional to sinθ and that due to dipole no.2 is proportional to cosθ. The vectors representing these two fields are however at 90^0time phase to one another. Hence the resultant field at point 'P' is the vector sum of two vectors at right angles to one another and proportional to sinθ and cosθ as illustrated in fig.2 (b). The resultant is, therefore, a constant independent of θ. If the short dipoles are replaced by a half wave dipoles the change in the pattern in a horizontal plane is not very great and this forms the basis of the crossed dipole antenna. If the field on a vertical axis above the antenna is examined, it is found that the electric vector rotates in a horizontal plane Fig.3 (a). The instantaneous field straight in a horizontal plane due to dipole no.1 is saying proportional to sinωt and in the direction OX. The instantaneous field due to dipole no.2 is proportional to cosωt and in the direction OY. The field pattern E as a function of θ and time, producing a circular pattern in the θ plane is given by

$$E = \sin\omega t\cos\theta + \cos\omega t\sin\theta \quad (1)$$
$$E = \sin(\omega t + \theta) \quad (2)$$
$$|E| = 1 \quad (3)$$

Thus at any value of θ, the maximum amplitude of E is unity at some instant during each cycle. The rms filed pattern is circular Fig.3(c). At instant of time the pattern is figure of eight of the same shape as for a single infinitesimal dipole. The instantaneous patterns are shown in Fig.3(c) The resultant filed is a vector of fixed amplitude rotating in a horizontal plane about a fixed axis. Reversal of the connections to one dipole reverses the direction of rotation.

III. Simulation results

According to the simulation results, it has been observed that from Fig.3,the VSWR value is high at the low frequencies and it will goes on decrease as the frequency increases from the 150MHz to 200MHz. Again the VSWR value increases as the frequency increases from 200MHz to 400MHz.Fig.4shows plot of gain versus frequency. From this plot it has been observed that the gain value is more negative below 200MHz, after 200MHz the gain value is almost constant and less negative up to 400MHz. Fig.5.shows that Radiation pattern characteristics of Crossed dipole antenna at downlink and uplink frequencies of the UHF Satellite Communication at phase angle0^0 ,180^0,90^0 and $270.^0$From the Radiation pattern characteristics it has been observed that there is no radiation in the vertical direction. Table I and TableII shows that main lobe magnitude, main lobe direction and angular width at the downlink and uplink frequencies of the UHF Satellite Communication. From Table1 and Table2 it has been observed that main lobe magnitudes are negative values around -2dB.
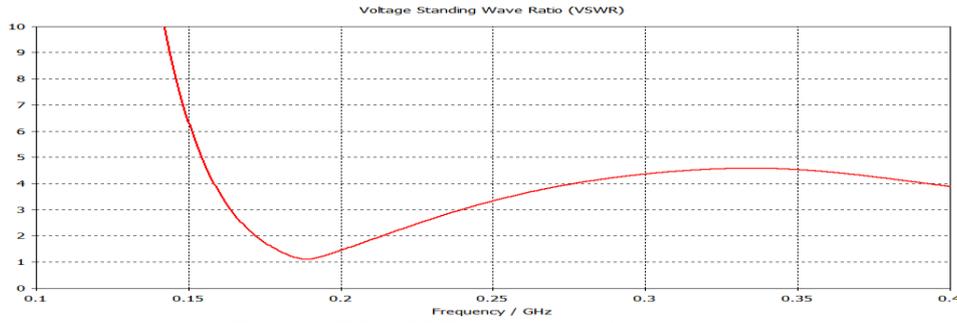
Fig. 3.VSWR ofUHF Crossed dipole antenna.
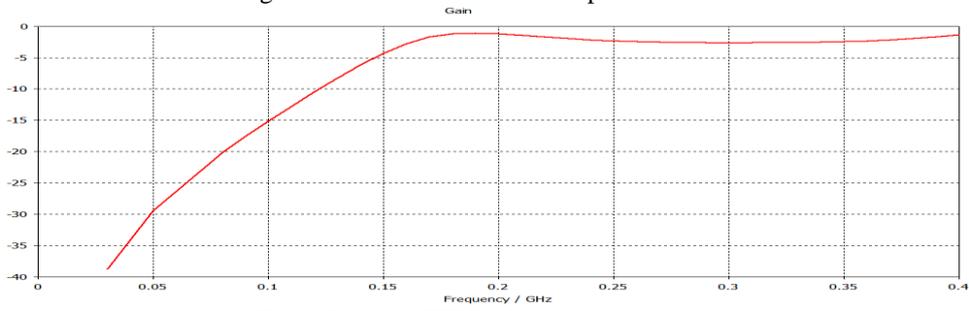
Fig. 4.Gain of UHFCrossed dipole antenna

LHCP @240 MHz   CUT PLANE @240 MHz

LHCP @250 MHz   CUT PLANE @250MHz

LHCP @260 MHz   CUT PLANE @260MHz

LHCP @270 MHz   CUT PLANE @270MHz

LHCP @290 MHz   CUT PLANE @290MHz

LHCP @300 MHz   CUT PLANE @300 MHz

LHCP @310 MHz   CUT PLANE @310 MHz

LHCP @320 MHz   CUT PLANE @320 MHz
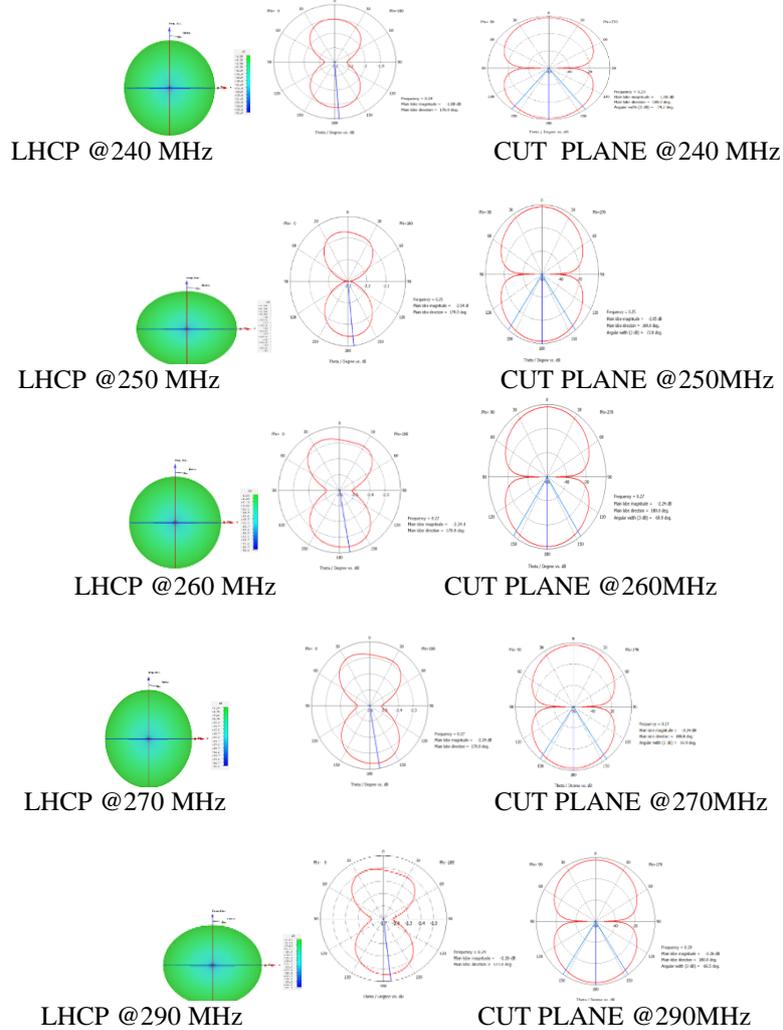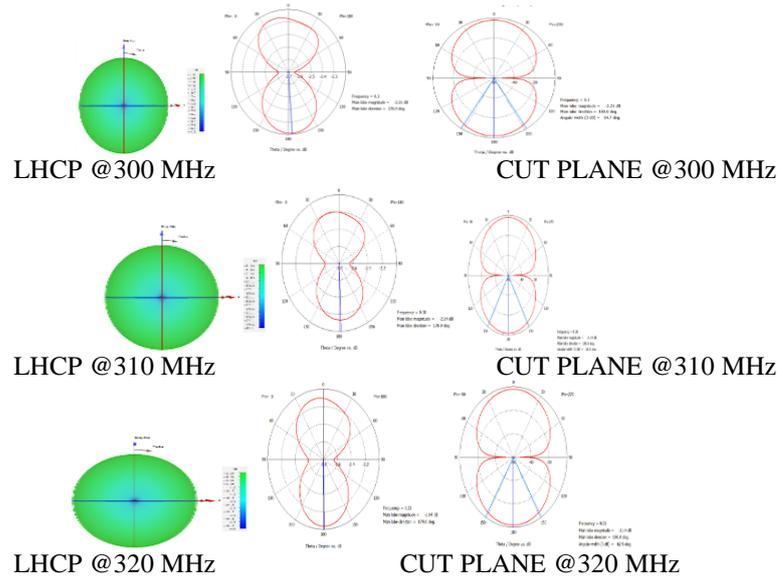
Fig. 5. Radiation patterns of UHF Crossed dipole antenna at various operating frequencies.

Table I

Main lobe magnitude, Main lobe direction at phase angle 0^0 & 180^0 for various frequencies

Frequency (MHz)	Main lobe Magnitude (dB)	Main lobe direction (Degrees)
240 MHz	-1.88	176.0
250 MHz	-2.04	174.0
260 MHz	-2.16	172.0
270 MHz	-2.24	170.0
290 MHz	-2.26	173.0
300MHz	-2.21	176.0
310 MHz	-2.14	178.0
320 MHz	-2.04	179.0

Table II

Main lobe magnitude, Main lobe direction at phase angle 90^0 & 270^0 for various frequencies

Frequency (MHz)	Main lobe Magnitude (dB)	Main lobe direction (Degrees)	Angular width (3dB)
240 MHz	-1.88	180.0	74.2
250 MHz	-2.05	180.0	72.8
260 MHz	-2.17	180.0	71.4
270 MHz	-2.24	180.0	69.9
290 MHz	-2.26	180.0	66.5
300MHz	-2.21	180.0	64.7
310 MHz	-2.24	180.0	62.9
320 MHz	-2.06	180.0	60.5

IV. Limitations of crossed dipole antenna

- From the simulation results such as gain and radiation pattern characteristics, it has been observed that gain and main lobe magnitude are negative values. For communicating with satellites the antenna gain as well as main lobe magnitudes both are must be positive then only the antenna can track the satellite directly if not ,the antenna cannot tracks the satellite. This is the main limitation of the crossed dipole antenna when it is used for UHF Satellite Communication applications.

- There is another limitation which is VSWR. For UHF Satellite Communication applications, the VSWR value should be low as possible and VSWR $\leq$ 3 is accepted. From the VSWR versus frequency characteristics, it has been observed that VSWR value is high value at the frequency range from 100MHz to 400MHz. This high value of VSWR is not appropriate for UHF Satellite Communication applications.

V. Conclusion and future work

It is concluded that the Crossed dipole antenna has been studied its characteristics and limitations for UHF Satellite Communication applications. The Crossed dipole antenna was simulated and analyzed for various characteristics such as VSWR, Gain and Radiation pattern characteristics at the downlink and uplink frequencies of the UHF Satellite Communication. From the simulation results, it has been observed that the Crossed dipole antenna cannot be used for communicating with Satellites because the gain value is negative and it is around -2dB at the downlink and uplink frequencies .Apart from this ,the main lobe magnitude values are also negative they are around -2.01dB from 240MHz to 320MHz. Moreover VSWR value is high and not accepted for UHF Satellite Communication. Bifilar helix antenna is the suitable antenna for communicating with Satellites because helix antenna has unique characteristics such as circular polarization, wide axial ratio and wide beam width. Our future work will bethe study, design, simulation, fabrication and testing of a bifilar helix antenna for various Communications like UHF, GPS, GLONASS, IRNSS and S-Band

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