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Design of Double Inclined Co-Axial Continuous Transverse Stub Antenna Array for Wireless Communication

P.Jothilakshmi*, Dr.(Mrs).S. Raju#

*Assistant Professor
Department of Electronics and Communication Engineering
Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India

#Professor & Head of the Department
*Department of Electronics and Communication Engineering
Thiagarajar College of Engineering, Madurai,Tamilnadu,India
Email: vishnujothi04@gmail.com

***Abstract*-The ever growing demands of wireless technologies are tending towards devices that are compact, multi functional with excellent performance and cost effective. The researchers are focusing on devices that are having a reduction in size and cost, with optimal performance in one hand and on the other hand they are also focusing on the efficient use of available spectrum. In both cases, antenna technology plays a major role in terms size, performance and cost. There exist many antenna technologies for size reduction, namely chip antennas and PCB antennas for wireless applications. Each technology has its own merits and demerits with respect to a chosen application. Co-axial continuous transverse stub (CCTS) antenna technology is a candidate for miniaturized antenna and variation in the structure can lead to multiple resonance which could ideally suited to present day wireless challenges. This paper proposes a novel CCTS structure christened as double inclined coaxial continuous transverse stub antenna array for multiple resonance between 3 GHz to 10 GHz. These operating frequencies are primarily suitable for high frequency wireless communication applications like Wireless Sensor Networks, Radar, and Commercial and Military application.**

***Index Terms*- Coaxial stub Antenna, Inclined CCTS, Directivity, Gain, Radiation pattern, Return loss.**

I. INTRODUCTION

Co-axial Continuous Transverse stub antenna array is a multimode structure and supports number of waveguide modes [1-10]. The inclined CCTS antenna occupies less space compared to normal CCTS antenna. This inclined structure is a derivative of the coaxial single stub CTS antenna. The dual inclined CTS antenna is the complete version of the single inclined model. Thus the structure is symmetrical about a general normal plane. Both the stub plates are inclined at equal angles from the normal plane. The double inclined structure is also compatible in construction point of view as, both stubs are symmetric and lofting suitable dielectric within them is easier. In this design the distance between the stubs is varying linearly from one end to another. In one end the distance between the stubs are less and in another end it is more. The less distance is for lower frequency of range and the larger distance is for higher frequency. This structure is the modified version of radial coaxial continuous transverse stub (CCTS) [10-17].

II. SINGLE INCLINED CCTS ANTENNA

As proposed in the general structure of the single element coaxial CTS antenna, the stub or parallel plates are the radial expansions of the outer conductor having a definite thickness. The distance between stubs (L_1) is fixed for un-inclined coaxial continuous transverse stub antenna. One of the two ports is taken up for input feed and the other is usually terminated in matched impedance or shorted. The proposed

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double inclined co-axial continuous transverse stub (CCTS) antenna structure is a derivative of the coaxial single stub CTS antenna. Here one of the two plates is inclined towards the normal of the stub plane, thus creating the single inclined structure. Thus the structure is symmetrical about a general normal plane, since both the stub plates are inclined at equal angles from the normal plane.

The double inclined structure is also compatible with construction point of view as, both stubs are symmetric and lofting suitable dielectric within them is easier. In this design the distance between the stubs is varying linearly from one end to another. At one end the distance between the stubs are less and in other end it is more. The less distance is for lower frequency of range and the larger distance is for higher frequency.

The stub width varies linearly from one end to another. Thus, the value L_1 is a minimum at one end and a maximum at the other. This is the basic idea of the single inclined structure, incorporating a variable stub length, thus creating a band of operation instead of just a single frequency of operation. The performance of the antenna varies with respect to inclination angle. Figure 1 shows the structure and cross section of single inclined coaxial continuous transverse stub (CCTS) antenna with design calculation formula.

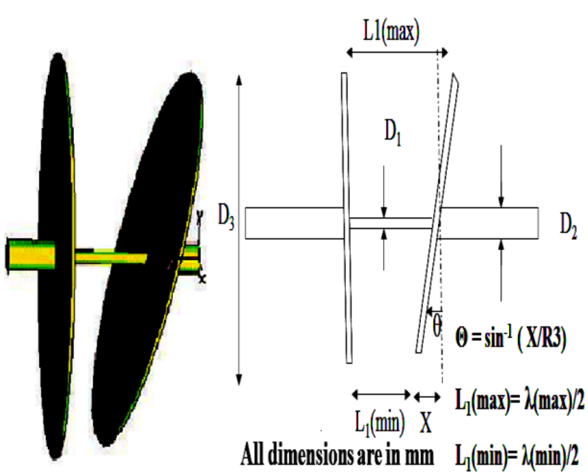

Fig.1. Structure of single inclined coaxial continuous transverse stub antenna

III. DOUBLE INCLINED SINGLE ELEMENT CCTS ANTENNA

The design of double inclined structures is similar to the basic model, the only difference is, the stubs are tilted by an angle of theta (θ) with respect to the position of stubs present in the basic model. The design for this structure includes the determination of the parameters as the width of the stub segment (L_1 (min) and L_1 (max)), angle of inclination of the inclined stub (θ), length of transmission line segment (L_2), dielectric constant of filler dielectric material (ε_r), diameter of inner conductor (D_1), diameter of outer conductor (D_2) and diameter of the stub (D_3). The proposed structure is shown Figure 2. The above structure is designed for 5 GHz and the stubs are inclined by an angle of theta (θ). The angle theta (θ) is chosen using the formula given in Figure 1 and then the distance between the stub, stub width is determined [17]. The dielectric constant of the chosen dielectric material is 2.08. Figure 2 shows the structure and cross sectional view of proposed dual inclined single element antenna structure.

The dimensions of this proposed inclined structure has been tabulated in table.1, which shows that the inclined structure radiates for multiple frequency bands with reduced size. The main advantages of present structure are symmetric with increased bandwidth. From these two models there is a need to reduce the design complexity. So instead of parallel inclined the dual inclined structures are preferred to get multiple frequency bands.

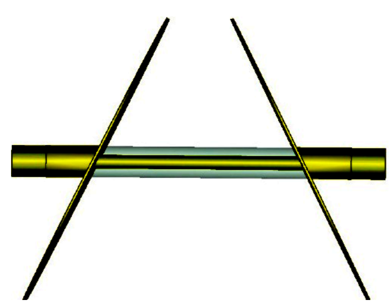

Fig.2. Structure of single inclined coaxial continuous transverse stub antenna

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Table 1: Physical dimensions of proposed dual inclined single element coaxial continuous transverse stub antenna array with Teflon (ε_r=2.08) as dielectric material

Sl. No	Component	Dimension	Material Used
1.	Stub diameter (D_3)	60 mm	Aluminium
2.	Inner conductor diameter (D_1)	3 mm	Brass
3.	Outer conductor diameter (D_2)	7 mm	Brass
4.	Stub thickness	1 mm	-
5.	Stub inclination in x-axis	25^0	-
6.	Total length of antenna array	116mm	-
7.	Dielectric material diameter	6.95 mm	Teflon

The proposed double inclined single element coaxial continuous transverse stub (CCTS) antenna is simulated using CST Microwave Studio and the results are presented below. Figure 3 and Figure 4 shows the return loss and radiation pattern plot of proposed double inclined coaxial CTS antenna, which shows that the proposed antenna structure radiates with centre frequency 6.6 GHz and 8.5 GHz with a 10 dB bandwidth of 290 MHz and 850 MHz respectively. The return loss for 6.6 GHz and 8.5 GHz are -23.26 dB and -20.12 dB which show that the performance of the double inclined single element CCTS antenna is good. The voltage standing wave ratio for the frequency 6.6 GHz and 8.5 GHz are 1.14 and 1.21 which shows that the proposed dual inclined CCTS antenna radiates with acceptable voltage standing wave ratio.

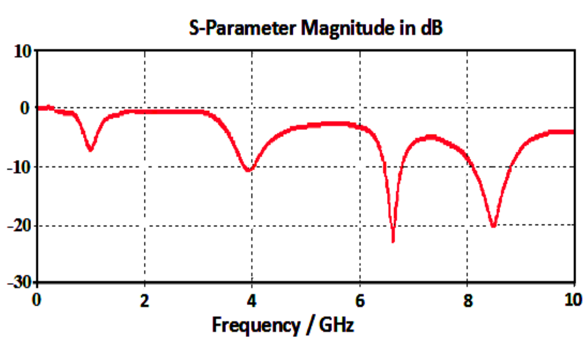

Fig.3. Return loss (S_{11}) plot of proposed inclined radial dual inclined single element coaxial continuous transverse stub antenna

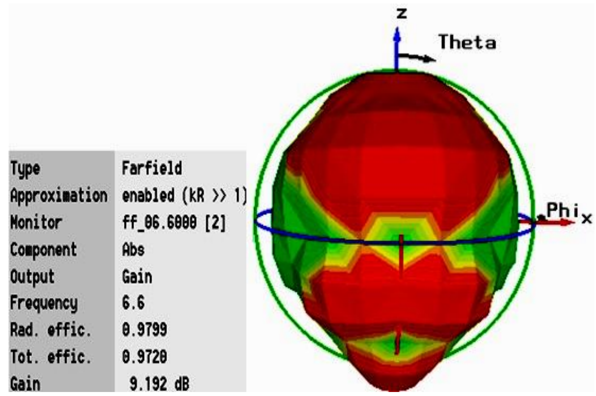

Fig.4. Three dimensional radiation pattern of dual inclined single element coaxial continuous transverse stub antenna at 6.6 GHz frequency

IV. ANALYSIS OF WITH DIFFERENT PARAMETRIC CHANGES

In the single element dual inclined CCTS antenna as discussed above resonated in only two designated frequencies. In order to make it multi resonant a double element dual inclined antenna array is proposed. The design formulae and the parameters are similar to a single element except another double inclined stub is added along the axis of the antenna. The inclination angle, distance between the two stubs and the dielectric material used in the connecting segment are optimized to get the required performance of the chosen multi bands. The following section gives the optimization done in the structure with respect to inclination angle and the dielectric material used in the connecting segment.

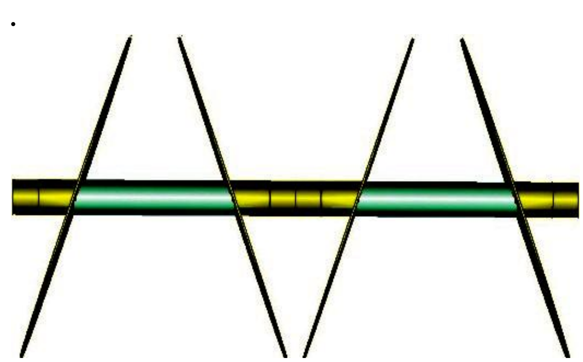

Fig.5. Structure of dual inclined two element CCTS antenna array

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Figure 5 shows the double inclined two element CCTS antenna. The parametric changes are made in this structure. This section presents the analysis of two element coaxial continuous transverse stub antenna with different inclination angle, stub thicknesses and dielectric material. Figure 6 shows the return loss plot of two element double inclined coaxial continuous transverse stub (CCTS) antenna for different inclination angles. The observation made for those inclination angles, indicates that the operating frequency could be shifted for different angles. The inclination angle for the present design can be selected according to the application of interest.

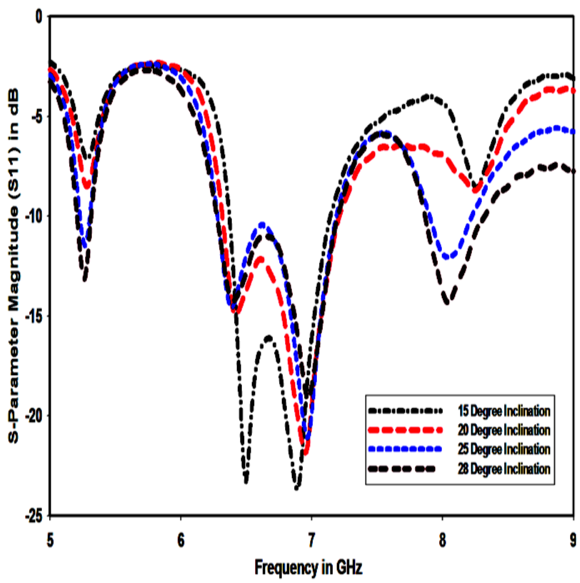

Fig.6. Return loss (S_{11}) plot of dual inclined two elements CCTS antenna array of different inclination angles

Figure 7 shows the simulated return loss plot of two element dual inclined coaxial continuous transverse stub antenna with different dielectric materials. There is a frequency shifting for different dielectric materials. There is a compromise between cost, material availability, ruggedness and losses. According to the material availability and cost, the chosen material for this design is Teflon with dielectric constant 2.08.

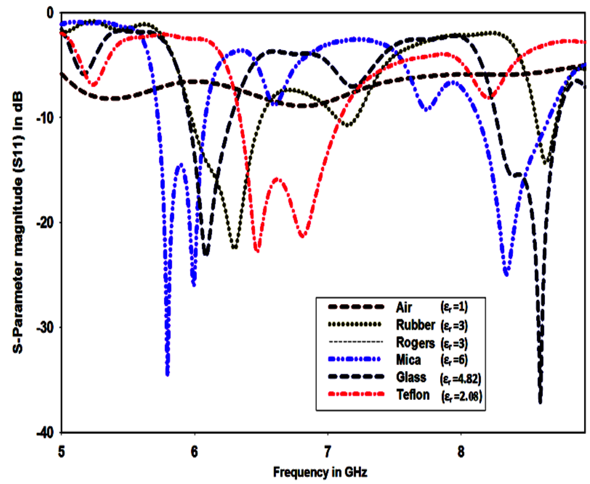

Fig.7. Return loss (S_{11}) plot of dual inclined two the elements CCTS antenna array of different dielectric materials

Figure 8 shows the return loss plot of two element dual inclined proposed antenna structure for different stub thicknesses, which shows that the stub with reduced thickness offers minimum loss. The double inclined two elements CCTS antenna with reduced stub thickness needs additional supporting element. So the thickness of stub chosen in this design is 1mm to eliminate additional support.

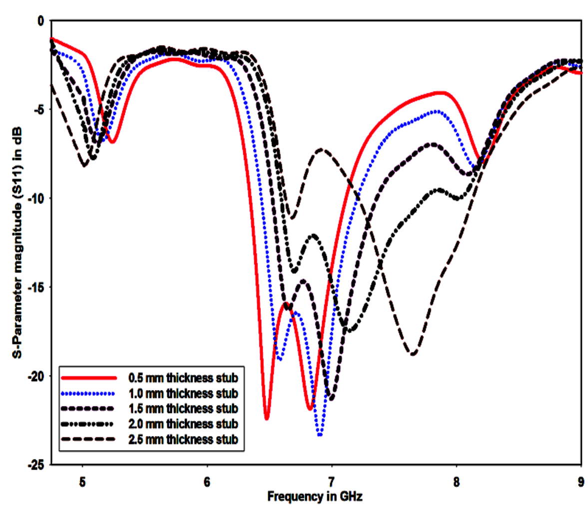

Fig.8. Return loss plot of proposed two elements dual inclined CCTS antenna array of different thicknesses of stub

V. SIMULATION OF PROPOSED DUAL INCLINED TWO ELEMENT CCTS ANTENNA

The design of two elements coaxial continuous transverse stub antenna with 25 degrees in x orientation of the antenna array. The dielectric material chosen is Teflon with dielectric constant (ε_r) as 2.08.The optimized proposed inclined two elements antenna structure dimensions are tabulated in table 2. It indicates that the length has been reduced compared to previous models. The dimensions of the proposed CCTS antenna are tabulated in table. 2.

Table 2: Physical dimensions of proposed dual inclined two element coaxial continuous transverse stub antenna array with Teflon (ε_r=2.08) as dielectric material

Sl. No	Component	Dimension	Material Used
1.	Stub diameter (D_3)	60 mm	Aluminium
2.	Inner conductor diameter (D_1)	3 mm	Brass
3.	Outer conductor diameter (D_2)	7 mm	Brass
4.	Stub thickness	1 mm	-
5.	Stub inclination in x-axis	25^0	-
6.	Total length of antenna array	116mm	-
7.	Dielectric material diameter	6.95 mm	Teflon

The proposed double inclined two elements CCTS antenna is simulated using CST Microwave Studio and the results are presented below. Figure 9 shows the simulated return loss plot of proposed continuous transverse stub antenna. From the simulated results it was observed that the return loss of the operating frequencies 3.11GHz, 6.02GHz, 6.7GHz is -30.13 dB,-35.35 dB and -36.77 dB. The voltage standing wave ratio of the operating frequencies 3.11 GHz, 6.02 GHz, 6.7 GHz are 1.213, 1.062 and 1.11 respectively. The observed results show that the performance of dual inclined two element CCTS is good. The 10 dB bandwidth for frequencies 3.11 GHz, 6.02 GHz and 6.7 GHz are 100 MHz, 420 MHz and 710 MHz respectively. Figure 10 and Figure 11 shows the radiation pattern of proposed two element dual inclined CCTS antenna. The observed results are tabulated in table 3, which shows that the results are good for triple frequencies.

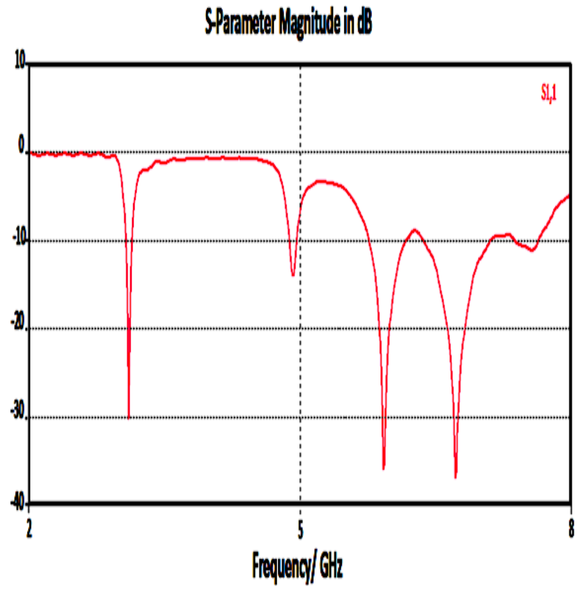

Fig.9. Return loss plot of proposed two elements dual inclined CCTS antenna array of different thicknesses of stub

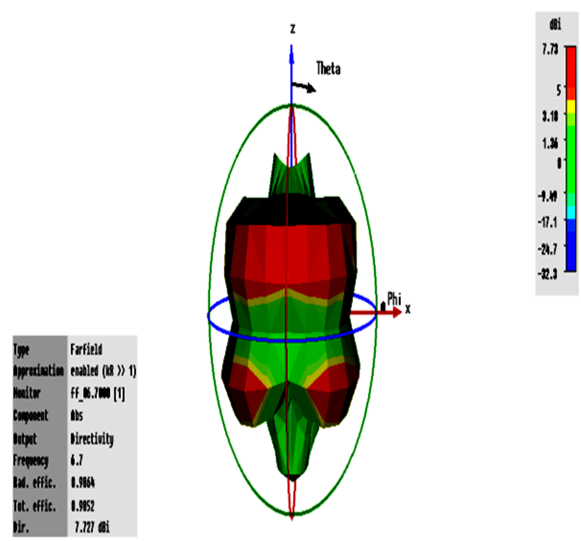

Fig.10. Three dimensional radiation pattern of dual inclined two element coaxial continuous transverse stub antenna at 6.7 GHz frequency

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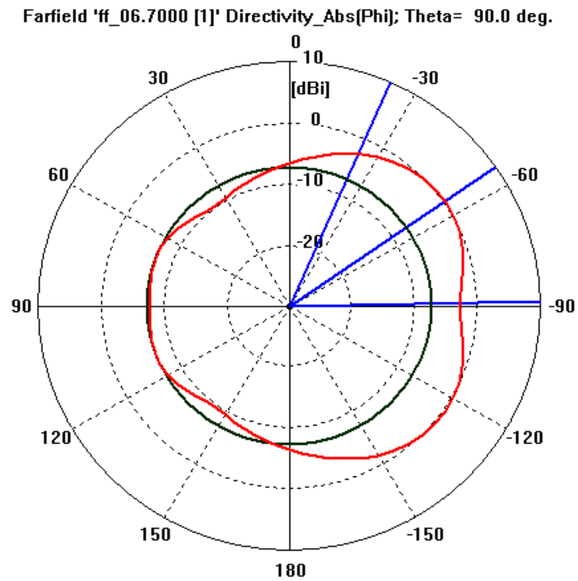

Fig.11. Polar radiation pattern of dual inclined single element coaxial continuous transverse stub antenna at 6.6 GHz frequency

Table 3 shows the extracted parameters in the simulation. The obtained results are good for all the three operating frequency bands. Table 3 shows the radiation efficiency of all three operating frequencies is good.

Table 3: Extracted parameters of proposed dual inclined coaxial continuous transverse stub antenna array

Parameters	Frequency in GHz		
	3.11	6.0200	6.7
Return loss (S_{11}) in dB	30.13	35.35	36.77
Gain (dB)	6.557	7.368	7.667
Directivity (dBi)	7.342	7.417	7.727
Voltage standing wave ratio (VSWR)	1.213	1.062	1.111
Radiation Efficiency (%)	83.46	98.89	98.64

VI. PROTOTYPE OF PROPOSED DUAL INCLINED CCTS ANTENNA ARRAY

The designed dual inclined coaxial CTS antenna is fabricated. Figure 12 shows the photograph of fabricated proposed antenna array structure for the inclination angle of 250 and materials used are Brass and Aluminum. The dielectric material used in this prototype is Teflon with dielectric constant 2.08. The antenna parameters are measured using network analyzer Agilent E8363B.

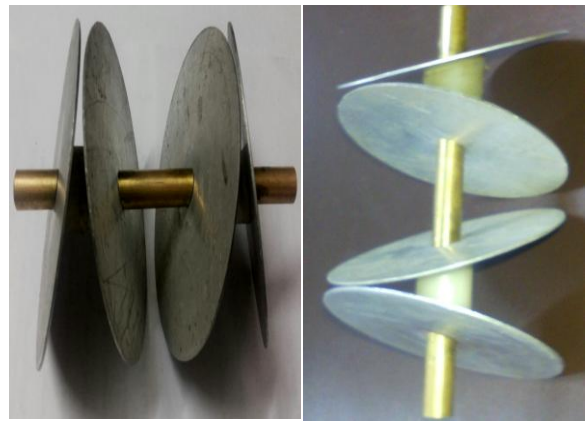

Fig.12. Prototype of a proposed dual inclined two elements coaxial continuous transverse stub antenna array in different views

Figure 13 show the return loss VBA file of proposed dual inclined two element CCTS antenna array. The exported VBA results were compared with simulated results.

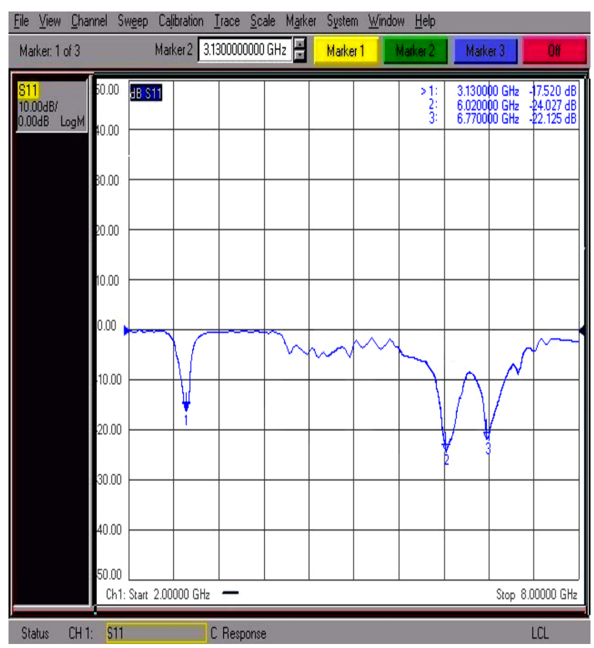

Fig.13. Return loss VBA file of fabricated dual inclined two elements CCTS antenna array.

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Table 4: Comparison between simulated and measured return loss and voltage standing wave ratio of proposed dual inclined CCTS antenna array

Simulated output		Measured Output		
Frequency (GHz)	S_{11} (dB)	Frequency (GHz)	S_{11} (dB)	VSWR
3.11	30.13	3.13	17.25	1.8823
6.02	35.35	6.02	24.03	2.0823
6.7	36.77	6.77	22.13	1.9519

Table 4 shows the comparison between simulated and measured results. There is approximately 97% of matching between simulated and measured results. The observed results show that the performance of the inclined antenna is good for multiple operating frequencies. Figure 13 shows the comparison between simulated and measured return loss. The observed results show that, there is a matching between three frequency bands and the results are tabulated in table.4. The measured results show that the prototype of proposed antenna radiates for three frequencies 3.13 GHz, 6.02 GHz, 6.77 GHz with a bandwidth of 110 MHz, 400 MHz and 695 MHz respectively.

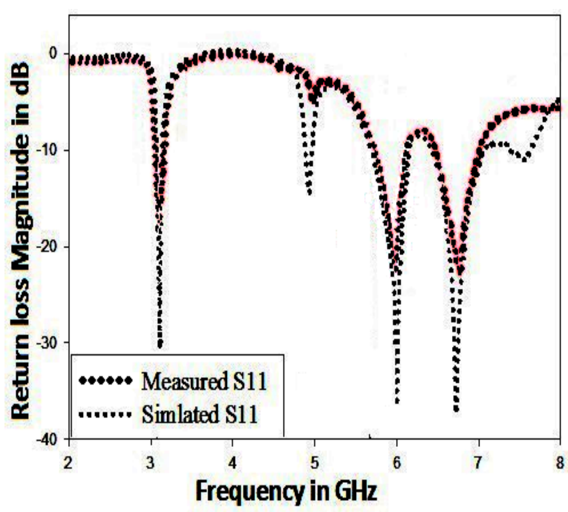

Fig.13. Comparison between simulated and measured return loss plot of a proposed dual inclined two elements CCTS antenna array.

VII. CONCLUSION

The observed results show that the two element array structure offers high gain, directivity and acceptable voltage standing wave ratio compared to single element dual inclined coaxial CTS structure. These results show that the proposed CCTS antenna structure is suitable to radiate for microwave frequencies. There is a compromise between losses and directivity. The proposed moderate two element structure could radiate for three multiple frequency bands which could be used for wireless communication applications like Wireless Sensor Networks, Radar, and Commercial and Military applications and LMI (Lockheed Martin Intersputnik) satellite communication transmitting section respectively.

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