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Design of 4X1 Microstrip Array Antenna for X-Band Satellite Communication Application

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Abstract

Thispaper represents design and analysis of 41 monopole microstriparray antenna for X-Bandsatellite communication applications. Proposed antenna design has been carried out with the single element antenna satisfying dual band operation in satellite communication range of 8.0 GHz-12.0 GHz. The significantability of the designed arrayantenna is to pass outstanding information acquired from satellites and the earth station repeaters with high gain and directivity. Proposed antenna array has been investigated and simulated in the Method of Moment (MOM) based CAD-FEKO EM-Solution software. The proposed antenna comprises dual inverted E-shaped configuration that enables dual band operations with ¡-10 dB reflection coefficient and 6 dB of gain in the X-Band satellite communication band. The radio antenna is manufactured on an FR-4 substrate consuming thickness of 1.6mm. Proposed array antenna shows balanced radiation pattern, stable gain over all working recurrence frequency which makes the designed antenna an appropriate contender for satellite communication applications.

***Key Words*:**array antenna; MOM based CADFEKO; dual band; FR-4 substarte; X-band.

1 Introduction

Nowadays, radio antenna configurations have gotten huge significance in the field of wireless communication applications. Extensive variety of use in all commercial, business as well as satellite-military specialized gadgets including advanced mobile phones, workstations, tablets, phablets, pagers, walki-talkies, satellite transportable terminals, military satellite radios, aerospace defense terminals and so forth is particularly demanding [1]-[4].Satellite radio system handles almost 50% of payload form conventional wireless communication systems including L-band (1.5 GHz-2.7 GHz), S-band (2.5 GHz-2.7GHz), C-band (3.7 GHz-6.4 GHz), X-band (8.3 GHz-12.5 GHz), Ku-band (12.7 GHz-17.8 GHz, Ka-band (18 GHz-31 GHz), V-band (36 GHz-51.4 GHz)bands available for satellite communications. Most X-band (8.3 GHz-12.5 GHz) satellite reception apparatuses are typically utilized to attempt the information transmission of military applications including telemetry and tracking systems [5]-[7].

In this paper,array antenna configurations of 21 and 41 for broadband satellite applications covering dual band operations have been exhibited. Proposed work started by considering a double band single elementantennadesign, which works 8.3 GHz-12.5 GHz of X-band. Array structure of 21 and 41 antenna alignments is then proposed with its parametric assessments to accomplish high efficiency, high gain, stable radiation pattern, matched impedance properties and more capacity.

2 Single Antenna Modelling and Conclusions

Antenna design has been carried out by considering the transmission line theory of microstrip antenna modeling [8]. Based on the design frequency of 10.00 GHz, antenna design calculations are performed on the basis of following equations [9]. Proposed antenna has been simulated in the MOM based CADFEKO EM-simulation software and fabricated over the low cost FR-4 substrate with effective dielectric constant 4.4 and height of 1.6 mm [10]. simulated antenna parameter are listed in table 1.

Simulated single element antenna geometry is shown in Fig. 1. Proposed antenna consists of dual E-Slot structures in back to back fashion arrangements. Due to E-slot, antenna radiates in dual frequency mode of propagation. Simulated single element antenna provides double band operation covering requisitions of X-band.Designed antenna indicates ¡-10 dB reflection coefficient bandwidths at achieved frequency bands. Simulated antenna return loss in dB is shown in Fig. 2.Proposed antenna reflects at 8.50 GHz and 11.89 GHz of operating band with ¡-10 dB reflection coefficient magnitude.

Simulated proposed antenna current distributions at dual band frequencies are shown in Fig. 3, indicates the surface current densities at peak resonating frequencies of X-band.Total gain of single element antenna is indicated by Fig. 8 (a). Modeled antenna attends 2.8 dBi of isotropic gain over the X-band resonating frequencies.

Wp= C/(4fr)*(r+1)$\hat{(}$-1/2) (6.1)

L=(L)/h=0.412((reff+0.3)(W/h+0.264)/(reff-0.258)(W/h+0.8)) (6.2)

Lp= Leff- L (6.3)

Single Element Antenna Parameters

Parameters	Calculated values
Substrate length (Ls) and width (W_s)	30mm
Patch length (L_p)	14mm
Patch width (W_p)	18mm
Feed line length (L_f)	13mm
Feed line width (W_f)	3mm

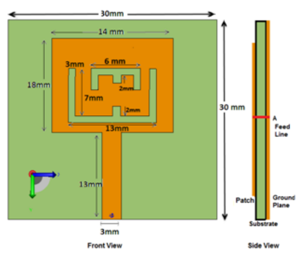

Fig. 1 Single element antenna geometrical details.

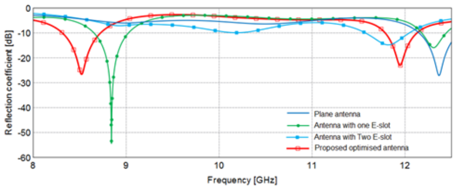

Fig. 2 Simulated single element antenna return loss plot (¡-10dB)with parametric details of E-shaped slot structures.

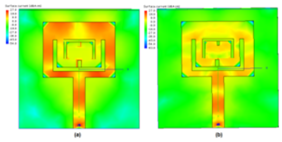

Fig. 3. Simulated single element antenna surface current distributionsat : (a) 8.50 GHz, (b) 11.89 GHz.

3 Two Element Array Antenna Modelling and Conclusions

Expanding those number for transmit and receive antennas, it reasonably offers improvements in the the throughput of the channel for each pairof antennas included in the system. By increasingnumber of patch elements,different essential parameters of MSA likewise beamwidth, gain, efficiency and many moreare used to be extended as per array configuration [11].Proposed antenna for 2X1 array configuration is shown in Fig.5. Designed antenna has 6045 mm total ground plane and the placement of two patches are divided eventually by /2 positioning separation in order to isolate the radiating port.

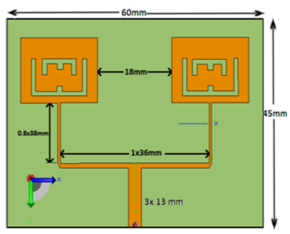

Fig.4. Proposed dual band 21 array antenna geometrical details.

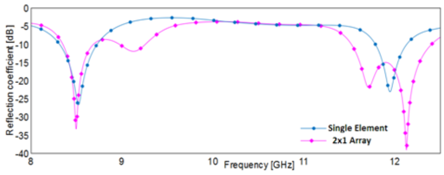

Fig.5. Reflection coefficient of simulated dual band single element and 21 MSA array.

Fig.5 shows reflection coefficient of 21 antenna compared with single element antenna. Simulated 21 array antenna shows improvements in the bandwidth with 600 MHz at 12.0 GHz frequency. Gain of designed antenna has expanded due to array structure. Design 21 array antenna provides 4dBi of isotropic gain over the simulating frequency as indicated in the Fig. 8 (b).Fig.6 shows proposed dual band 41 array antenna geometrical details. Designed antenna array has total dimensions of 65130 mm and 18 mm of spacing between the radiating patches with 70 mm of separation between feeder lines.Proposed antenna provides matched impedance characteristics at operating frequencies due to well-designed quarter transformer feed network.

4 Four Element Array Antenna Modelling and Conclusions

Simulated 41 array antenna reflection coefficient bandwidth improvement has been shown in Fig.7. Proposed array antenna shows 4.3 % bandwidth improvement at 8.5 GHz center frequency and 4.7% improvements at 11.5 GHz center frequencies of dual band results.

Due to array structure, antenna total gain has been rigorously improved upto 6 dBi as shown in Fig.8 (c). Fig. 8 shows the gain improvements in the single element antenna, and 21 and 41 MSA array antenna configurations respectively.

Fig. 9 shows simulated antenna stable 8-shaped omnidirectional radiation patterns at the X-band of frequencies with up to -30 dB cross polar values. Proposed antenna attends 85% of operating efficiency at X-band frequency as shown in Fig. 8. (b).

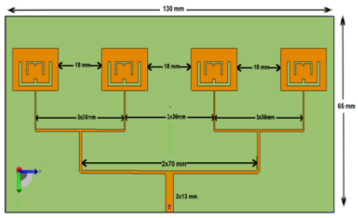

Fig.6. Proposed dual band 41 array antenna geometrical details.

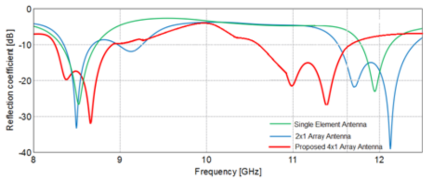

Fig.7. Reflection coefficient of simulated dual band single element and 21 and 41 MSA array.

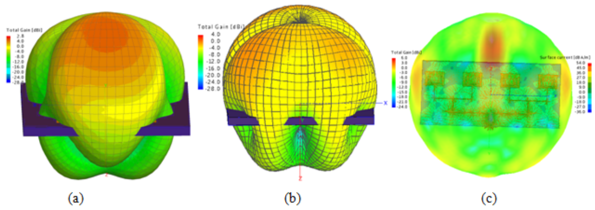

Fig.8. Simulated isotropictotal gain in dBi: (a) Single element antenna, (b) 2x1 Array antenna, (c) 4x1 Array antenna.

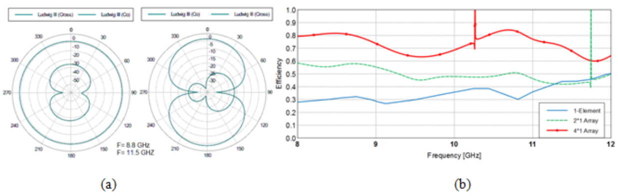

Fig.9. (a) Simulated radiation pattern of proposed 4x1 array antenna.; (b) Efficiency of proposed 4x1 array antenna.

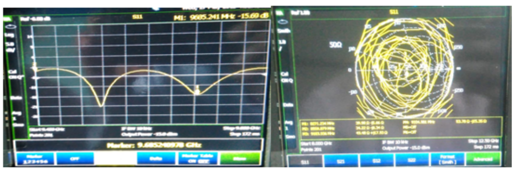

Fig.10 Measured reflection coefficient and smith chart of proposed41 array antenna.

Measured 4 x1 array antenna reflection coefficient and smith chart is shown in Fig.10.Simulated and fabricated 4x1 array antenna shows fine correlation between simulated and measured results [12].

5 Conclusion

Design of dual inverted E-shaped41microstrip array antenna for X-band satellite communication application has been presented. Proposed 41 array antenna has been investigated and analyzed on FR-4 substrate and modeled over CADFEKO antenna design software to operate over X-band of satellite communication frequency of 8 GHz to 12 GHz. Proposed antenna shows the dual band operations with improvements in the single element antenna, 2-element array antenna and 4-element array antenna. Transmission bandwidth improvements have been shown with proposed 41 array antenna. Proposed antenna attends up to 6dBi of total gain due to array structure. Simulated antenna provides 85% of operating efficiency indicating stable and omnidirectional radiation patterns. Proposed antennaprovides challenging commitmentsby means oflow-cost effective solutions at X-band satellite-military applications.

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