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Band Reconfigurable Multi Port Satellite Antenna for C and Ku Band Applications

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***Abstract*—The fast development of wireless technology and continues increase in the number of users in satellite communication results in spectrum congestion and limited bandwidth. This attracts increasing interest on the design of band reconfigurable satellite antennas which can help to use spectrum resources for satellite communication more efficiently. This paper depicts an outline to design a novel compact and low profile band reconfigurable MIMO (Multiple Input Multiple Output) microstrip patch antenna for possible applications in C and Ku band satellite applications. The proposed antenna structure comprises a modified E and hammer shaped patch, in which E shaped patch is for C band applications and the hammer shaped is for Ku band applications. The band reconfiguration ability of the antenna is obtained by placing two ports simultaneously on a same antenna feed by a dual 50 Ω line feed. The performance of the antenna is fabricated on low cost FR-4 substrate with a dielectric constant of $\in_r = 4.3$ and the same is tested for return loss, impedance bandwidth, directivity, surface current and impedance.**

Keywords: C-band, CST, Ku-band, Microstrip antenna, MIMO.

I. INTRODUCTION

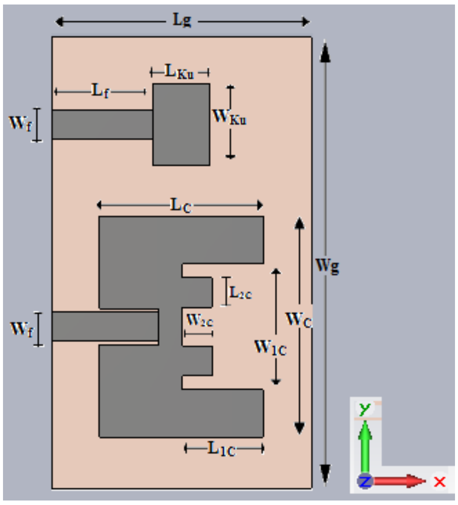
A typical satellite link involves the uplink and downlink signal. A signal from an earth station to a satellite is an uplink signal. The satellite then receives and amplifies the signal and retransmits it back to earth this signal is known as downlink signal. The uplink frequency is kept higher than the downlink frequency for proper isolation and adequate characteristics for downlink signal, but as the electromagnetic spectrum is a shared resource, limited and regulated, that is more and more congested with the increasing number of satellite users **[1], [2]**. The further exploitation of the available frequencies by other services possesses practical and regulatory difficulties. This fact has triggered the wireless communication community to find new and more efficient ways of utilizing the frequency spectrum. The expected scenario is certainly directed towards the size reduction of the multiple frequency band antennas of low profile, enhanced portability and multi-functionality. Nevertheless, with the increase of frequency bands, the design complexity associated with antenna also intensified. To fulfill the great demand of multi band operations in a single component for various wireless communication services, high performance antennas with desired radiation properties have to be developed. For the designing of communication module, it is common to integrate antenna subsystem which can reciprocate certain standard requirements by wireless system. However, implementing and integrating more than one function in the single communication system may help in cost minimization and size reduction of the complete module. Integrating the C-band and Ku-band satellite application in a single antenna module may help in utilizing the spectrum resources more efficiently. In general this can be done in two ways either using a band/frequency reconfigurable antenna [**3**] or by using a MIMO (Multiple Input Multiple Output) antenna [**4**]. The band reconfiguration antenna is obtained by adjusting the path of currents on the antenna or by altering the geometry of the radiating device [**3**] but the shortcoming of such design was that they can work only on a single band at a time. The concept of MIMO antenna [**4**]-**[15]** has emerged as a possible solution as they can work on the multiple inputs and multiple outputs simultaneously with proper isolation between them.

In this paper, a novel band reconfigurable multi port satellite antenna for C and Ku band applications is presented as a new band switching MIMO patch antenna. The antenna structure comprises a modified E and hammer shaped patch, in which E and hammer shaped patch is for C and Ku band applications respectively. The dual band operation of the antenna for uplink and downlink frequency of C and Ku bands is obtained by placing dual ports simultaneously on a same antenna feed by a dual 50 **Ω** line feed. The proposed antenna design is studied and simulated using CST Microwave Studio.

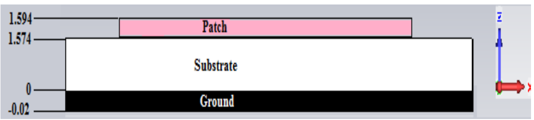
The paper is organized as follows. Section II discusses the band reconfigurable concept and introduces our newly proposed design, Section III discusses the results.

II. ANTENNA DESIGN

The proposed MIMO satellite antenna consists of two patch element with common substrate and ground as shown in Fig.1.



(a)



(b)

Fig.1 (a), 1(b): Front and bottom view of antenna design

A dual 50Ω line feed is located at the left center of patch's in which port 1 and 2 is for C and Ku band patch's respectively. The antenna is designed on a low cost FR4 (lossy) substrate which is 1.574 mm thick and having dielectric constant ϵ_r = 4.3. The dimensions of the optimized antenna are given in Table 1.

Table 1: Parameter description of antenna design

Parameter	Description	Dimensions(mm)
L_g	length of ground and substrate	26.4
W_g	width of ground and substrate	32.84
L_C	length of E shaped patch	16.6
W_C	width of E shaped patch	24.44
L_{1C}	length of patch cut in E patch	8.2
W_{1C}	width of patch cut in E patch	12.8
L_{2C}	length of centre leg in E patch	3
W_{2C}	Width of centre leg in E patch	3
L_{Ku}	length of hammer shaped patch	5.8
W_{Ku}	Width of hammer shaped patch	8.3
L_f	Length of line feed	10.3
W_f	Width of line feed	3

III. RESULT AND DISSCUSSIONS

One can vary the dimension of radiating patch to change the resonating frequency and other desired characteristics. The proposed antenna is designed first for downlink frequency band and the uplink frequency band is introduced by changing the dimensions of the radiating patch, which further culminates in variation of current and hence the resonating frequency. Thus alteration in patch dimensions strongly controls the resonant modes of the patch antenna, and this altered patch dimensions results in a desired uplink and downlink frequency bands.

In the given antenna design we proposed two patch element. One for C band application which is of modified E shape and other for Ku band application which is of hammer shape. Both of the patch elements is feed by a dual 50 Ω line feed in such a position that they provide proper isolation between both bands and result in constructive radiation characteristics for desired bands and distractive radiation characteristics in undesired bands.

For both ports i.e. port-1for E shaped patch and port-2 for hammer shaped patch, the proposed antenna design is simulated for return loss, resonance frequency, impedance band-width, surface current, directivity and radiation pattern. The return loss, radiation patterns, surface currents and smith chart is shown in Fig. 2, 3, 4, 5, 6 and 7 respectively for port-1.

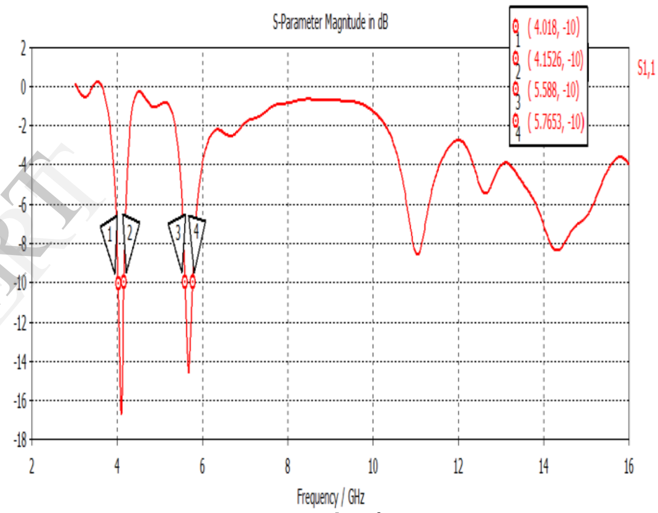


Fig. 2: Return loss for port-1

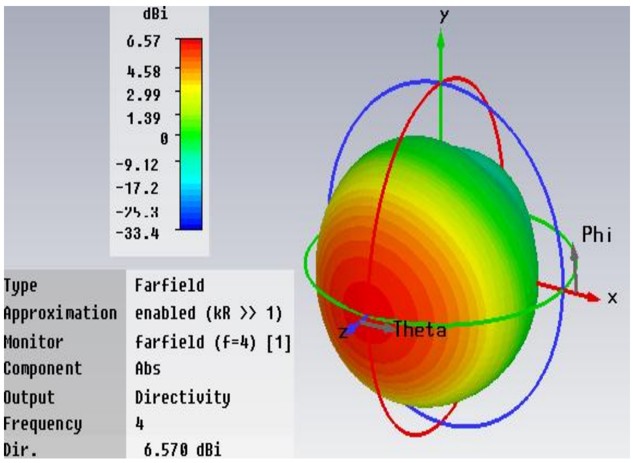


Fig. 3: Radiation pattern and directivity for port-1 at 4 GHz

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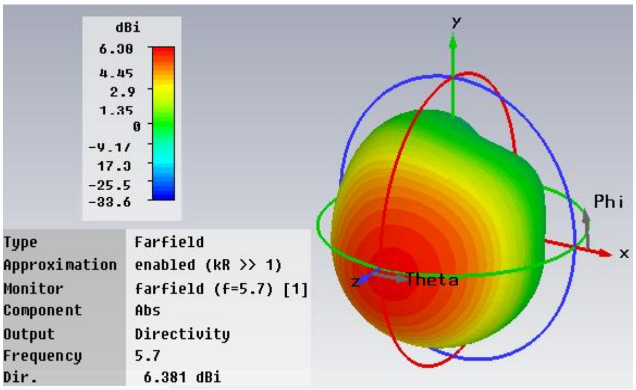

Fig. 4: Radiation pattern and directivity for port-1 at 5.7 GHz

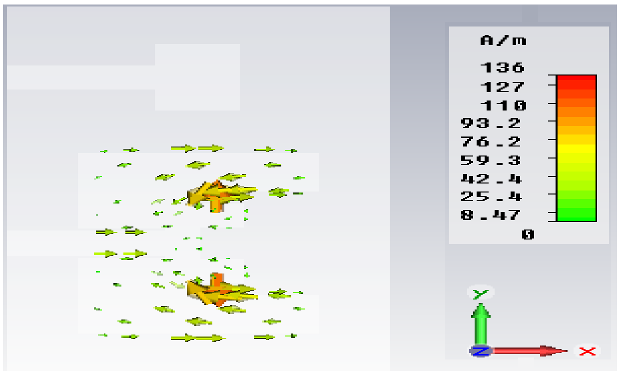

Fig. 5: Surface current for port-1 at 4GHz

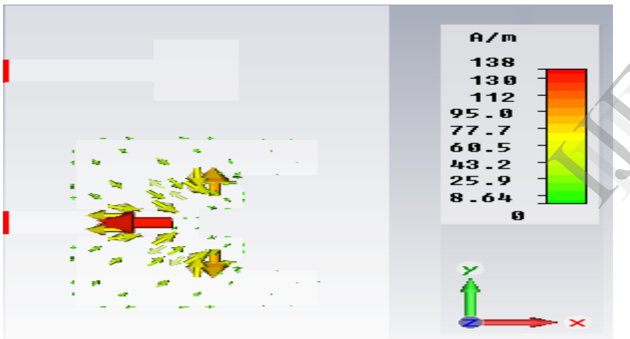

Fig. 6: Surface current for port-1 at 5.7 GHz

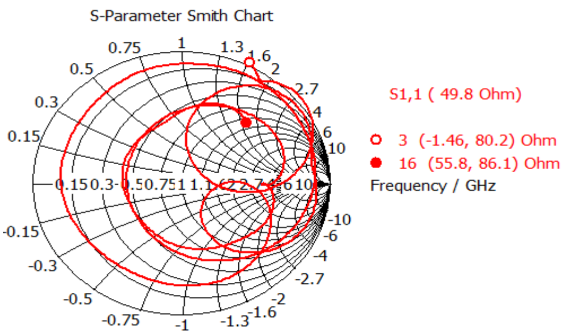

Fig. 7: Smith chart for port-1

The resonating frequencies for port-1 are 4 GHz and 5.7 GHz as depicted in fig. 2. At 4 GHz which is the downlink frequency for C-band the return loss is -17 dB and bandwidth of 134.6 MHz is measured. The radiation pattern at resonant frequency of 4 GHz with a directivity of 6.57 dBi is shown in Fig 3. Surface current in Fig 5 imparts the information regarding the current flowing through patch.

While at 5.7 GHz which is the uplink frequency for C-band the return loss is -15 dB and bandwidth of 177.3 MHz is measured as depicted in Fig 2. The radiation pattern at resonant frequency of 5.7 GHz with a directivity of 6.381 dBi is shown in Fig 4. Surface current and smith chart in Fig 6, 7 imparts the information regarding the current flowing through patch and input impedance respectively.

The port-2 is simulated similarly and all results are summarized in Table 2.

Table 2: Summarized result for dual port

Port	Band	Resonance frequency f_r (GHz)	Return loss (dB)	Band-width (MHz)	Directivity (dBi)	Input Impedance
1	C-Band (downlink)	4	-17	134.6	6.57	49.8
	C-Band (uplink)	5.7	-15	177.3	6.381	
2	Ku-Band (downlink)	10.8	-13	406	5.156	49.8
	Ku-Band (uplink)	14.7	-25	1437	7.343	

The return loss for both ports is shown in fig. 8 representing four different resonance frequencies with related return loss and band-width.

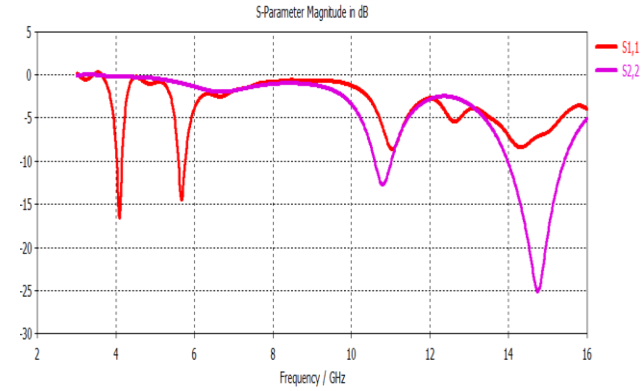

Fig. 8: Return loss for dual ports

The antenna design resonates at four different frequencies in the range of 3 to 16 GHz. It is evident from the table 2 given above that the resonance frequency of 4 and 5.7 GHz are obtained through port-1 which covers the satellite downlink and uplink frequency bands of C band. Similarly resonance frequency of 10.8 and 14.7 GHz is obtained through port-2 which covers the satellite downlink and uplink frequency bands of Ku band.

For both of ports, the antenna input impedance is 49.8Ω, thus the design does not requiring any extra matching device.

IV. CONCLUSION

A novel band reconfigurable multi port satellite antenna for C and Ku band applications has been presented. The antenna provides MIMO operation with sufficient radiation characteristics, band-width, directivity and minimum return loss. The paper detailed the concept of MIMO operations with the help dual line feed for this new design. The design can be used for satellite applications in C and Ku bands simultaneously with sufficient isolation and radiation characteristics for uplink and downlink frequencies to solve the problem of band congestion on a single chip. The design is compact enough (26.4 × 32.84 × 1.62 mm) to fit in any radio device and offer the input impedance of 49.8 Ω (≈50Ω) for all ports, thus does not requires any extra impedance matching device.

Future work includes comparison of measured and simulated result and can be extended for more number of ports to include more satellite bands in MIMO operation.

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