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AUKŠTŲJŲ DAŽNIŲ TECHNOLOGIJA, MIKROBANGOS

A Compact Wideband Antenna on Dielectric Material Substrate for K Band

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Introduction

Owing to the rapid growth of wireless communication technology, miniature antenna plays a significant role for small size multifunctional devices. In recent days, all communication devices need to be small in size, compact, lightweight, in short should be portable. Moreover portable devices obligatory to operate wider frequency range applications to use in different areas or countries [1, 2]. Due to the availability of unused bandwidth in k/ka band, many researchers are concentrating towards K band application oriented antenna design. Recently, demand of satellite based portable communication devices are increasing noticeably, especially vehicle tracking, portable satellite station, weather forecasting etc. Antenna size reduction with wideband operation capability is still interesting topic for communication engineering researchers. A considerable research effort is being given to antenna miniaturization to integrate with small form factor wideband operating devices without compromising the overall performance [3]. There are several techniques have extensively studied by many researchers, such as using reactive impedance substrate [4], artificial magnetic conductor [5], modified ground plane [6], EBG substrate [7], Metamaterials [8], multilayer Dielectric Substrates [9] etc. Use of ceramic material substrate is one of the effective techniques for antenna miniaturization. Due to higher dielectric constant of the ceramic material substrate, the overall size of antenna can be reduced significantly with our compromising the overall performance [10]. Many antenna technology researchers have comprehensively examined the use of ceramic material substrate for miniature antenna design in their article [11, 12]. A 24x24x4.8 mm^3 low-temperature co-fired-ceramic (LTCC) fractal antenna array designed and achieved 8% bandwidth with 8.9 dBi gain [13]. A miniature antenna was designed using thick truncated textured Ceramic Substrate with the dimension of 14x13.6 mm^2 at 1.88 GHz resonant frequency and obtained 35 MHz of bandwidth [14]. Miniaturized 2x2 and 4x1 stacked patch antenna array designed using using low-temperature co-fired-ceramic (LTCC) substrates and achieved 10.1% bandwidth with 10.35 dBi gain [15]. However, in terms of antenna size reduction or bandwidth enhancement there is still scope to explore the antenna miniaturization with better performance.

In this paper, an 8 x 10 mm^2 patch antenna is designed on 1.5 mm thick Aluminium tri-oxide (Al_2O_3) ceramic material substrate and achieved 830 MHz of 10-dB bandwidth, 3.5 dBi peak gain and 97.3% of average radiation efficiency. The proposed antenna is comparatively smaller in size, wider bandwidth, better gain and higher radiation efficiency achieved than the reported antennas. In addition, co and cross polarization of radiation pattern and E-H field current distribution are analyzed.

Antenna design and configuration

The proposed modified S-shaped small patch antenna is designed and analyzed by using computer aided commercially available 3D full-wave electromagnetic field simulator HFSS [16, 17]. The design process begins with determining the patch dimension with substrate properties and thickness. Although the available equations of the antenna patch dimension are based on rectangular shape planar antenna, the size of the proposed antenna need to be customized due to cutting slots from the conventional rectangular shape. The size width and length is determined by using basic mathematical equation (1, 2) [18]:

$$w = \frac{c}{2 f_o}\sqrt{\frac{\varepsilon_r + 1}{2}}, \quad (1)$$

$$L = \frac{c}{2 f_o \sqrt{\varepsilon_r}} - 2\Delta l. \quad (2)$$

In the above equations (1 & 2), c is the speed of light in vacuum, f_0 is the center target frequency, L is the length and W is the width of the radiating copper patch. By using equation (3), the effective dielectric constant of the substrate can be calculated [18]

$$\varepsilon_e = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{2}(\varepsilon_r - 1)\sqrt{(1 + \frac{10h}{W})}, \qquad (3)$$

where ε_r is the relative dielectric constant and h is the thickness of the substrate. The antenna electrically looks larger than its physical dimensions, due to the fringing field around the periphery of the patch. The increment to the length, Δl due to fringing field can be expressed as [18]

$$\Delta l = 0.412h \frac{(\varepsilon_e + 0.3)\left[\frac{w}{h} + 0.8\right]}{(\varepsilon_e - 0.258)\left[\frac{w}{h} + 0.8\right]}. \qquad (4)$$

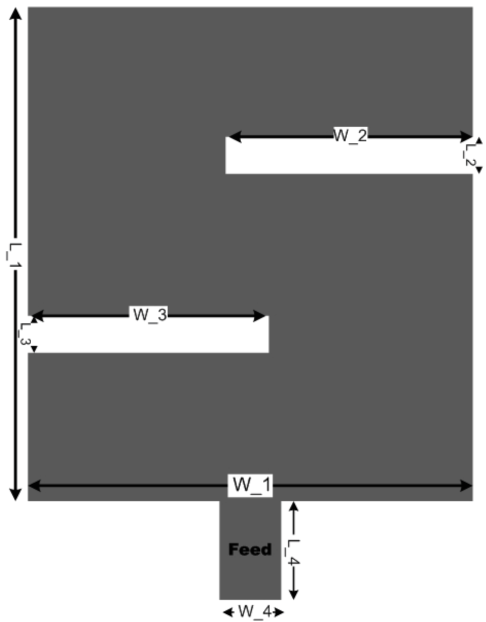

Fig. 1. Geometry of the proposed antenna

The profile of the proposed antenna shown in Fig. 1 is designed on a 1.5 mm thick Aluminium tri-oxide ceramic substrate whose relative permittivity is 9.8 and relative permeability is 1. Due to higher dielectric constant and no tangent loss Al_2O_3 ceramic material is chosen as substrate. Compare to conventional less expensive widely used FR4 substrate, Al_2O_3 ceramic material substrate reduce the overall antenna size dramatically and performs much better in terms of bandwidth, gain and efficiency. For the projected antenna design, S shape is obtained by cutting slots from the rectangular copper patch. By cautiously adjusting the length, width and slots of the proposed antenna, two resonant frequencies at 20.13 GHz and 20.53 GHz preferred in the entire operating frequency band from 19.97 GHz to 20.80 GHz. A 2 mm long 1 mm wide microstrip line is used to feed the antenna. There are no conducting ground plane is used, the antenna is expected to be placed on non-conducting surface. A 50-Ω SMA connector will be used for RF signal input at the end of the microstrip feed line. The detailed design parameters of the proposed antenna are tabulated in Table 1.

Result and analysis

By using commercially available Ansoft's high frequency structure simulator (HFSS) the computed results of the proposed antenna are analyzed and optimized.

The most important parameter of the antenna result return loss is shown in Fig. 2. The achieved bandwidth (Return loss <-10 dB) of 830 MHz in the operating frequency from 19.97 GHz to 20.8 GHz. The voltage standing web ratio (VSWR) of the entire operating frequency band is illustrated in Fig. 3. It can be clearly seen that, the VSWR value is less than 2 which is desired.

Table 1. Detailed design parameters of the proposed antenna

Parameters	L_1	W_1	L_2	W_2	L_3	W_3	L_4	W_4
Value(mm)	10	8	1	4.5	1	4.5	2	1

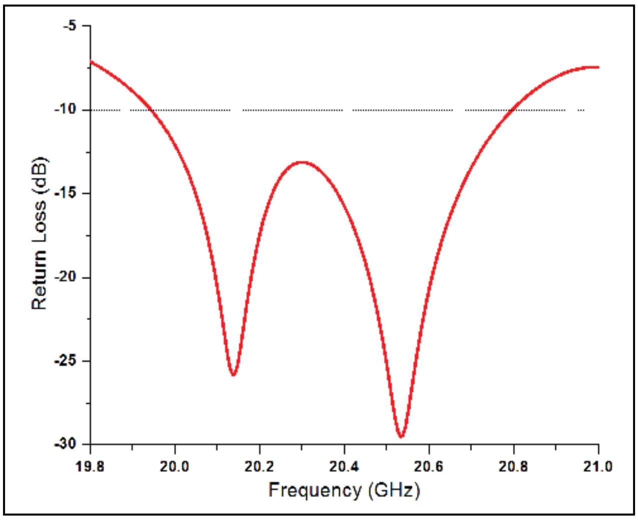

Fig. 2. Computed return loss of the proposed antenna

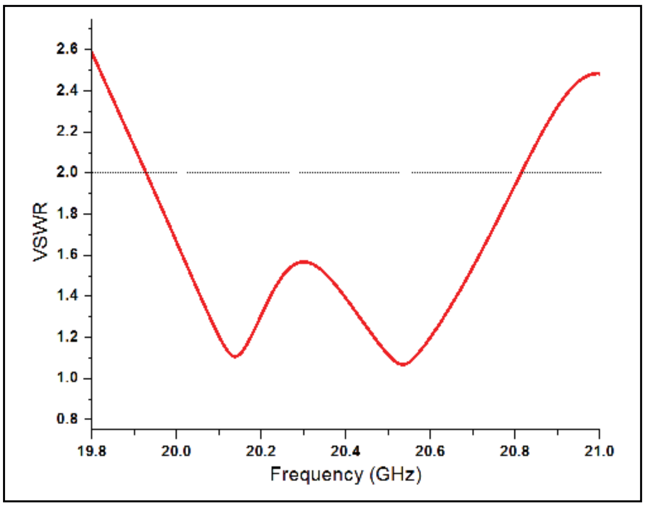

Fig. 3. VSWR versus frequency of the proposed antenna

Fig. 4 shows the gain of the proposed antenna. It is observed from the result that average gain achieved 1.98 dBi in the whole operating frequency band. The gain 1.87 dBi and 2.08 dBi obtained at two preferred resonance 20.13 and 20.53 respectively. The graph of radiation efficiency vs. frequency is illustrated in Fig. 5. It is evidently noticed that, the average radiation efficiency of the proposed antenna is 96.5 %, which considered as highly efficient.

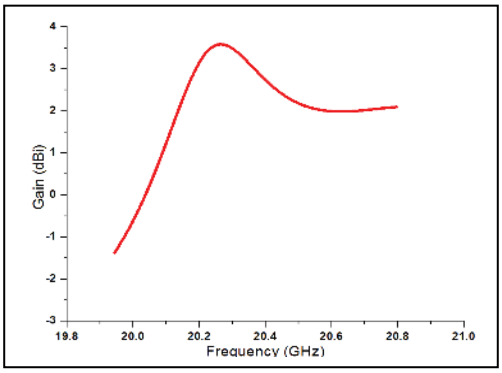

Fig. 4. Achieved gain of the proposed antenna

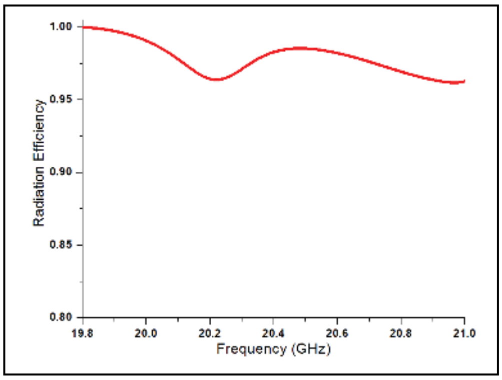

Fig. 5. Radiation efficiency of the proposed antenna

Fig. 6 shows the radiation pattern for E-plane and H-plane of the proposed antenna at resonance frequency of 20.13 GHz and 20.53 GHz.

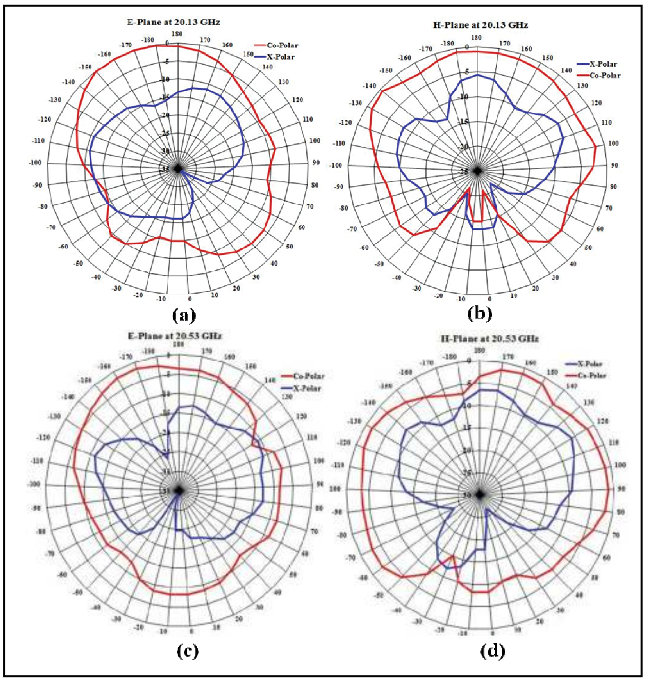

Fig. 6. Co-Cross polar Radiation pattern of the proposed antenna (a) E-plane at 20.13GHZ, (b) H-plane at 20.13GHz (c) E-plane at 20.53 GHz and (d) H-plane at 20.53 GHz

The effect of cross-polarization is lower than co-polarization which is desired. The cross polar effect is higher in the second resonant 20.53, Therefore, easily interpreted from the radiation pattern that the cross polar effect increase with higher frequency. Moreover, the designed antenna produces stable radiation pattern at two resonant frequency band where cross polarization effect is lower than co-polarization. Having stable and symmetrical radiation pattern is a considerable advantage for patch antenna. During the construction of an antenna array the radiation pattern tend to be steadier along the operating frequency band.

Conclusions

A compact low profile wideband microstrip patch antenna designed and analyzed for K band application in this study. The proposed antenna can be integrated with wireless devices operate from 19.97 GHz to 20.8 GHz frequency band. Return loss, VSWR, Gain, radiation pattern and radiation efficiency of the proposed antenna are analyzed and optimized by using finite element method based 3D-fullwave electromagnetic simulator. The overall size of the antenna is appreciably abridged by using high dielectric ceramic material substrate. The proposed antenna can be a competitive solution for the current needs to be adopted with small multi technology wireless devices compare to other available wideband antennas.

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A wideband modified S shaped electrically small microstrip patch antenna on Aluminium tri-oxide ceramic substrate is designed and analyzed in this paper. The proposed microstrip line fed miniature patch antenna designed by using high frequency electromagnetic solver and the computed results are analyzed by using finite element method. It is observed from the obtained results that, 830 MHz bandwidth (Return loss <-10dB), 2dBi average gain, 97.33% of average efficiency are achieved in the operating frequency from 19.97 GHz to 20.80 GHz for K band satellite applications. Furthermore, the co-cross polarization of the radiation pattern and the current distribution for E-H field is analyzed. Ill. 6, bibl. 18, tabl. 1 (in English; abstracts in English and Lithuanian).

M. Habib Ullah, M. T. Islam, J. S. Mandeep, N. Misran, N. Nikabdullah. Kompaktiška plačiajuostė antena ant dielektriko pagrindo K dažnių juostai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 7(123). – P. 75–78.

Sukurta ir tiriama plačiajuostė modifikuota S formos mikrojuostelinė antena ant aliuminio trioksido. Antena sukurta naudojant aukštojo dažnio elektromagnetinį sprendimo įrenginį, gauti rezultatai analizuoti baigtinių elementų metodu. Gauti rezultatai rodo, kad 830 MHz dažnių juostoje (nuostoliai <-10dB), esant 2dBi vidutiniam stiprinimui, 97,33% vidutinis efektyvumas pasiektas darbiniuose dažniuose nuo 19,97 GHz iki 20,80 GHz K dažnių juostos palydovinėms sistemoms. Il. 6, bibl. 18, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).