Design of a Compact Dual Band Microstrip Antenna for Ku-Band Applications

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ABSTRACT
A new design of dual band compact microstrip antenna is proposed for Ku-band applications. Dual band is achieved using three pairs of thin slits from the sides of a rectangular patch and feeding with a microstrip feed line. The result shows that a return loss of -32.9dB is achieved at the first resonant frequency of 12.72GHz, and -14.4dB is obtained at the second resonant frequency of 14.4GHz frequency with VSWR ≤ 2 indicating improved matching conditions. The results of simulation are return loss, radiation pattern, VSWR, and bandwidth represented. The design is performed by using Ready-madeSoftware package Zeland- IE3D. The antenna is fabricated using thin film and photolithographic technique and measured using the Vector Network Analyzer. The final result shows that good agreement between the simulated and measured results.

Keywords  
Microstrip antenna, Ku-band, Dual band

1. INTRODUCTION
Microstrip antennas have been one of the most innovative topics in antenna theory and design in recent years, and are increasingly finding application in a wide range of modern microwave systems [1]. Inherently they have numerous advantages like easy to fabricate using standard integrated circuit techniques, have low profile, are conformal, and can be easily integrated in arrays with electronic components. Nevertheless, microstrip antennas typically suffer from narrowband radiation (a few percent of center frequency), low gain, poor polarization purity, tolerance problem and limited power capacity. However, applications such as frequency tuning take advantage of the inherent narrow bandwidth of the microstrip antenna.

Systems such as satellites, global position system (GPS) are required to operate at two different frequencies that are very far from each other. Microstrip antennas can avoid the use of two different single band antennas. A variety of methods has been proposed to obtain dual frequency operation. Such as loading slits [2], using slots in the patch [3], [4], loading the patch with shorting pins [5], [6] and [7], using stacked patches [8], [9], [10] and [11] or using two feeding ports [12] are the most exploited ones. In addition, there are planar antennas of special geometries to achieve dual-band operation [13].

The Federal Communication Commission adopted a First Report and Order (First R&O) to permit non-geostationary satellite orbit (NGSO) and fixed-satellite service (FSS) providersto operate in various segments of the Ku-band, and adopted rules and policies to govern these operations. NGSO FSS can provide a variety of new services to the public, such as high-speed Internet access, other types of high-speed data, video and telephony services. Because of its ability to serve large portions of the earth’s surface, NGSO FSS can bring advanced services to rural areas. The Commission also adopted technical criteria so that NGSO FSS operations can share spectrum with incumbent services on a co-primary basis without causing unacceptable interference to them and without unduly constraining future growth of incumbent services or NGSO FSS system flexibility [14].

In this paper, a simple new compact design of single layer single patch element with microstrip feed line is proposed for dual frequency operation in Ku-band. The design and optimization resulted in a downlink frequency of 12.72GHz and uplink frequency of 14.4GHz. The most obvious application in the Ku-band is aircraft, spacecraft and satellite based communication system.

2. COMPACT DUAL BAND MICROSTRIP ANTENNA DESIGN FOR KU-BAND APPLICATIONS
The dual frequency operation of microstrip antennas has been studied by a number of researchers using stacked patches with two separate feeds for each frequency band and polarization. In these structures, a combination of two different feeds is observed. These feeds are composed of two separate microstrip lines [15], two apertures [16], one via and one microstrip [17], two separate probes [18], and one microstrip and one aperture [19]. Other designs with a single electromagnetically coupled feed are also available [20], [21].

In general, stacked patches suffer from disadvantages such as thick substrate, difficult manufacturing, and high cost. On the other hand, using single feed antennas can reduce the complexity and the cost of the receiver front-end.

The geometry of the proposed microstrip antenna was modeled using the classical equations [22]:

\[ W = \left( \frac{C}{2f_0} \right) \frac{\varepsilon_r + 1}{2} \]  

\[ L = \left( \frac{C}{2f_0 \sqrt{\varepsilon_r}} \right) - 2\Delta \]  

\[ \varepsilon_r = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2} \sqrt{1 + \frac{10h}{W}} \]
\[ \Delta l = 0.412h \left( \varepsilon_r + 0.3 \left( \frac{W}{h} + 0.264 \right) \right) \]

\[ \left( \varepsilon_r - 0.258 \left( \frac{W}{h} + 0.8 \right) \right) \]

Where \( W \) is the width of the patch, \( L \) is the length of the patch, \( \Delta l \) is the additional length on each end due to the fringing field along the widths, \( \varepsilon_r \) is the dielectric constant of the substrate, \( c \) is the speed of light in a vacuum, \( f_0 \) is the target frequency and \( h \) is the thickness of the substrate.

The antenna is initially designed to operate in dual frequency at Ku-band based on the above equations and consequently optimized to obtain the most preferable size of the patch using full wave method of momentof Zeland-IE3D electromagnetic simulator. The geometry of the proposed antenna is shown in Figure 1. We use the rectangular shape due to its compactness and small size. The area of the proposed shape equals \( (5.7 \times 7.96) \) mm\(^2\) which is small compared to the conventional microstrip antenna. The proposed antenna is constructed from Rogers RT/Duroid 6010 substrate material with dielectric constant \( (\varepsilon_r=10.2) \), substrate height \( (h=1.9\) mm), loss tangent \( (\tan\delta = 0.023) \). The patch is fed from the downside by a 1.77mm wide and 2.21mm long microstrip feed line.

The antenna performance was studied by the commercially available simulation software Zeland IE3D. The simulated return loss of the proposed antenna is depicted in Figure 2. This Figure shows that the patch has two resonance frequencies of 12.72GHz and 14.4GHz having reflection coefficients of -32.9dB and -14.4dB, respectively. The -10dB bandwidth is 680MHz at the lower resonance frequency and 990MHz at the higher resonance frequency.

The value of VSWR is less than 2 at both resonance frequencies indicating acceptable matching conditions of the design system.

3. RESULTS AND DISCUSSION

The antenna performance was studied by the commercially available simulation software Zeland IE3D. The simulated return loss of the proposed antenna is depicted in Figure 2. This Figure shows that the patch has two resonance frequencies of 12.72GHz and 14.4GHz having reflection coefficients of -32.9dB and -14.4dB, respectively. The -10dB bandwidth is 680MHz at the lower resonance frequency and 990MHz at the higher resonance frequency.

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To verify the simulation results we fabricated specimens of the proposed antenna structure and a photograph of such Specimens is shown in Figure 4.
The fabricated specimen of the proposed antenna.

The measured return loss of the proposed antenna is shown in Figure 5. We have achieved a 399 MHz bandwidth, ranging from 12.503 GHz to 12.902 GHz on the 1st resonance and 300 MHz ranging from 14.102 GHz to 14.402 GHz on the 2nd resonance.

The simulated and measured return losses of the proposed antenna are shown in Figure 6. The resonant frequencies are shifted from 12.72 GHz to 12.7 GHz on the lower band and from 14.4 GHz to 14.2 GHz on the upper band. Deviation between the simulation and measurement may be attributed to the excitation of surface waves that occurs in the substrate layer as well as to the manufacturing defects.

4. CONCLUSION

In this paper, a new patch configuration to execute dual frequency operation at Ku-band with three pairs of slits using microstrip feed line have been proposed. The design simulation has been carried out by the use of IE3D-Full-Wave EM Simulation Package. The fabrication of the proposed antenna is performed with slits and a Rogers RT/Duroid 6010 dielectric substrate and is excited by a 50 Ω microstrip transmission line. Good results have been found at dual frequencies 12.72 GHz as downlink and 14.4 GHz as uplink. Satisfactory agreement between the simulated and measured results was found. This antenna is nominated to be applied for the satellite applications which require simultaneous transmit/receive functionality at widely separated frequency bands.

5. FUTURE WORK

The isolation between the two bands must be improved. The deviation between the simulation and measurement must be reduced. Measuring the radiation pattern of the fabricated antenna and compare it with simulation results. Multiple resonators antennas and wider bandwidth can be realized.

6. REFERENCES


