A Review on Design of Planar Antennas Satellite Applications

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Review on Design of Planar Antennas for Satellite Communication Application

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Abstract— This paper is about study of various microstrip patch antennas designed for satellite communication applications using various performance improvement techniques. From the appearance of the satellite communication we need to improve two key aspects in the communication systems: The quality of the service (greater quality and bandwidth of the signal) as well as the costs (smaller investment for the operation and maintenance). One of the ways to improve these two aspects is the miniaturization of communication components using microstrip antenna. The objective of this paper is to compare various techniques of designing microstrip antenna for the purpose of satellite communications.

Key words: microstrip, antenna, array, Ku- Band

I. Introduction

An antenna is one of the most important elements in the RF system for receiving or transmitting signals from and into the air as medium. The microstrip antennas have been object of study for researchers around the world with the purpose to use them in the telecommunications with the objective of reducing size, cost and improving the quality in the communications [1].

The microstrip antennas are designed in such a way that its structure dissipates the power in the particular direction in form of radiation when applied with electrical signal. The important advantages of these planar antennas includes low profile, adaptability to the form of the structure, simple and cheap manufacturing and can work on different frequencies and different polarizations [2]. However, common microstrip antennas are suffering from limitations like narrow bandwidth, limited power capacity and tolerance problems. To overcome its inherent limitation of narrow impedance bandwidth, many techniques have been suggested.

Authors have studied diverse forms of patches [3], substrate [4], and so on, in order to improve the benefits of the microstrip antennas and to especially extend its applicability in the diverse areas of the telecommunications and in the satellite communications that have as much demand and in that needs a greater miniaturization of its components.

With the development of the satellite technologies and its consequent miniaturization it appeared that microstrip antennas giving the possibility of reduced costs, size and maintaining or improving the quality of the satellite and terrestrial links. With low cost and size was possible carry out the satellite technology to more people around the world, to transform forever the way it will communicate between each human.

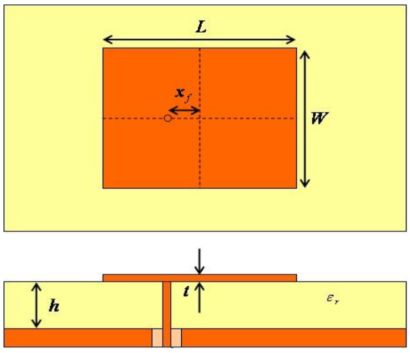


Fig. 1: Microstrip Patch Antenna

The most obvious application in the Ku-band is aircraft, spacecraft and satellite based communication system. In satellite communication mostly circularly polarized radiation patterns are required which can be easily achieved with different shapes of patch [5]. In order to obtain higher gain they can also be transformed into array structure. A phased-array microstrip patch antenna designed using different antenna element as shown in Fig.2, have more advantages over lens or reflector antenna for satellite applications due to the distribution of power amplification at the elementary radiation level, higher aperture efficiency, no spillover loss, no aperture blockage and produces better reliability.

The geometry of the proposed microstrip antenna and phased array antennas as shown in Fig.1 and Fig.2 can be modeled using the classical equations from [6].

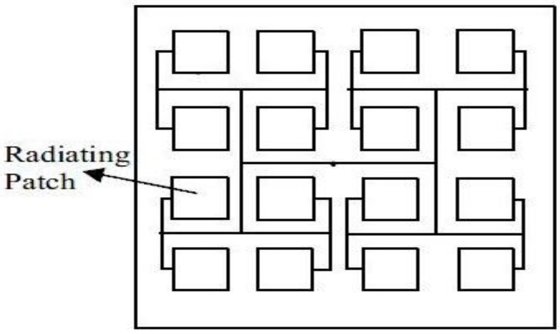


Fig. 2: Phased array Microstrip Antenna

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

$$h = \frac{0.3c}{2\pi f_o\sqrt{\varepsilon_r}} \quad (2)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (3)$$

$$\Delta L = \frac{0.412h(\varepsilon r+0.3)(\frac{W}{h}+0.264)}{(\varepsilon r-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (5)$$

$$L = L_{eff} - 2\Delta L \quad (6)$$

$$L_g = 6h + L \quad (7)$$

$$W_g = 6h + W \quad (8)$$

Where W is the width of the patch, L is the length of the patch, ΔL is the additional length on each end due to the fringing field along the widths, ε_r is the dielectric constant of the substrate, ε_{eff} is the effective dielectric constant, c is the speed of light in a vacuum, f_o is frequency and h is the thickness of the substrate. After taking account the design requirements such as bandwidth and dielectric constant, the antenna is initially designed to operate in dual frequency at Ku-band and consequently optimized to obtain the most referable size of the patch using full wave method of HFSS electromagnetic structure simulator.

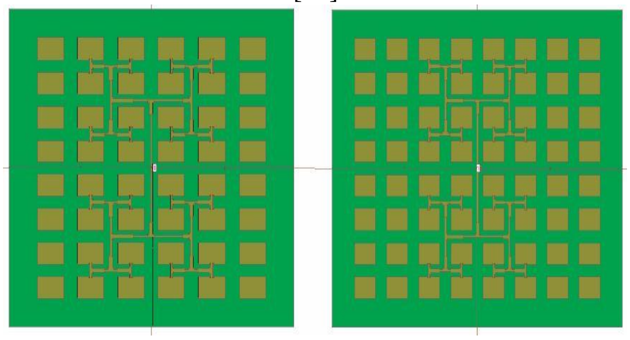
II. RELATED WORK

Flat panel antenna arrays adopting microstrip antenna as a driving element can provide a low profile and greater agility in mobile satellite communication systems and therefore have attracted much attention [7]. The radiation efficiency of array, however, is not high due to the power loss in the feed network and the drawbacks of the microstrip antenna. A common challenge in the design of antennas for satellite communication is to improve the efficiency of the array and then maximize the antenna gain in a limited space, which is the main focus of the reported work.

The bandwidth of an antenna is mainly determined by the thickness, the nature of the dielectric substrate and the geometry of the antenna. To expose the bandwidth matter in simple planar structures and to give a benchmark in terms of space and bandwidth, a rectangular patch was sized [8].The dimensions of the antenna can be deduced from analytical expressions. Increasing the width of this antenna is one of factors controlling its bandwidth [9]. Nevertheless, it is very difficult to obtain a satisfactory result with a simple shape microstrip patch antenna.

By selecting simple rectangular shaped patch and substrate material of low dielectric constant like Rogers RT/Duroid 5880, FR-4 and Glass PTFE it becomes simple and handy to design microstrip patch antenna and forming an array structure to obtain better results.

A study was done on patch antenna array to investigate the effect of parasitic elements using IE3D (Zeland) software shows one row and two rows of passive elements on each side of the array antenna as depicted in Fig.3. The different values of return loss and VSWR and the corresponding frequency for 4x8 array antenna with and without parasitic elements are listed in Table 1. The resonant frequency increases as the number of rows of parasitic elements increases [10].



(a) (b)

Fig. 3: Passive elements on each side of the array antenna (a) one row and (b) two row [10]

Table 1 shows the minimum values of return loss, VSWR and the corresponding resonance frequency for 4x8 antenna arrays with and without parasitic elements. This concludes that the operating frequency of the array can be controlled by the number of parasitic elements around it.

Case/Parameter	**Frequency (GHz)**	**Return Loss (dB)**	**VSWR**
array antenna without parasitic elements	12.46	-28.7	1.0357
array antenna with one row of parasitic elements	12.52	-21.14	1.1785
array antenna with two rows of parasitic elements	12.6	-21.2	1.161

Table 1: Different case/parameters and their values

In microstrip patch antenna to obtain dual frequency operation variety of methods has been proposed. Among them, loading slits, using slots in the patch, loading the patch with shorting pins, using stacked patches, or using two feeding ports are the mostly exploited ones. In addition, there are planar antennas of special geometries to achieve dual-band operation [11] which presents a simple compact design of single layer single patch element with microstrip feed line for dual frequency operation in Ku-band. The design and optimization carried out to operate at downlink frequency of 12.54GHz and uplink frequency of 14.15GHz.

The radiating patch is basically a rectangular structure and by implementing some popular configuration to execute dual frequency operation at Ku-band with three pairs of thin slits from the sides of a rectangular patch and feeding with a microstrip feedline is been proposed in [12] and is shown in Fig. 4. This antenna depicts that below -10dB the single layer antenna attained the bandwidth of 90MHz from 12.48GHz to 12.57GHz and as well the bandwidth of 60MHz from 14.13GHz to 14.19GHz.

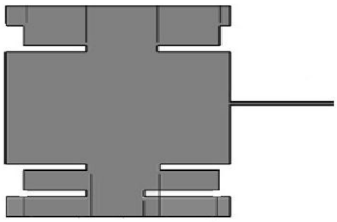


Fig. 4: Three slip patch [12]

In order to obtain a good isolation between transmitting and receiving bands, another technique which can be employed is Passive Phased Array Feed Design [13] consisting of four slot patch elements with two orthogonal polarizations for dual band operations and two distribution networks for Tx/Rx band. Compared with a standard patch antenna, the slot patch antenna has a top ground plane with vies surrounding all sides to prevent surface waves on the upper surface of the substrate and improve the pattern shape and cross polarization level.

The proposed array feed was fabricated on 32 mil Roger RO4003C material. The simulated and measured isolation across the whole Tx band is near 55 dB, protecting the receive amplifier from strong transmit signal bleed through. Thus this antenna provides a promising way to minimize two-way link feed size and demonstrates that a planar antenna is a feasible and effective solution for low cost and high performance.

The design of a compact dual frequency microstrip antenna proposed for Ku-band applications with initial geometry is shown in Fig. 5 with two inverted L shape slots on the patch in order to excite two frequencies and to decrease the dimensions of the patch [14]. The location and dimensions of each slot determine the resonance frequencies and also VSWR and is feed with aperture coupled method in order to decrease the undesirable coupling effects between feedline and the patch and to increase the reliability of feeding performance particularly to use in military and space applications. The bone shape aperture, which helps to increase the bandwidth of antenna at resonant frequencies, is excited by a 50Ω microstrip line. The maximum return loss of -18.66 dB and -19.79 dB and bandwidth of about 2% and 7% occurred at two frequencies of 11.5 GHz and 14 GHz respectively.

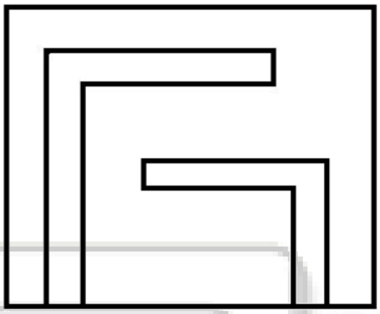


Fig. 5: Two L shaped slotted patch [14]

Authors have designed and optimized a simple compact single layer coaxial feed rectangular microstrip patch antenna to operate in Ku-band satellite application by introducing different notches and slits in the rectangular patch so that it can resonate at three different frequencies in [15]. On introducing the two slits as shown in Fig. 6, on the radiating patch shows dual band operation at 12.52 & 14.88 GHz with appreciable BW of 777.5 MHz & 2.0136 GHz making it applicable for Satellite Communication.

Fig. 6: Different slots on the patch [15]

Frequency	Return loss	VSWR
11.16 GHz	-18.9	1.95
12.5 GHz	-23.64	1.11
14.8 GHz	-34.34	0.33

Table 2: List of frequencies and other parameters

III. ANALYSIS AND DISCUSSION

With the advent of above mentioned techniques and methods it is been found that the slit implantation on the patch technique, probe feeding and introducing parasitic elements around array showed the best results for the practical applications. These all different design generates different results and characteristics which are all discussed in the Table 3.

Substrate Material	**Feeding technique**	**Frequency (GHz)**	**Return Loss(dB)**	**VSWR**	**Gain (dB)**
Teflon	Microstrip line feed	12.5	-21.14	1.17	NR
Roger RO4003 C	-do-	12.54	-23.83	NR	NR
		14.15	-14.04	NR	NR
FR-4	Aperture coupled feeding	11.5	-18.66	NR	6
		14	-19.8	NR	6
Glass PTFE	Probe Feeding	12.5	-23.64	1.1	6.3
		14.8	-34.3	0.33	6.3

Table 3: Comparison of different parameters

*NR- not reported

It is also been found that by implementing different slots and notches of different shapes on the radiating patch produces multiple frequency of operation in a single antenna. Hence it proves to be a useful tool to generate dual frequency operations in the antenna for various telemetry and satellite applications.

IV. CONCLUSION

This review paper describes the different techniques and methods for designing a microstrip patch antenna for Ku Band applications. From this it is concluded that it is possible to build a planar array antenna from microstrip patch antenna as a single antenna element to obtain much better and improved antenna parameters, which can become a good candidate for satellite communication applications.

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