Design of Wideband Dual-polarized Microstrip Antennas

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Abstract

This study investigates wideband dual-polarized microstrip antennas. These antennas are used to prevent deterioration of transmission quality caused by terminal interference or multipath fading, which usually occur when many terminals are used in limited space such as hot-spot zones. The experimental results showed that the impedance bandwidth (SWR≤2) of 33.24 % and the peak gain of 8.44 dBi (at 2.11 GHz) were obtained by the frequency band under 2.5 GHz. Designed originally for triple service band, the proposed antenna, with its simple structure, may easily be mass-produced and may have various commercial applications.

1. Introduction

Recently, information and communication technologies are undergoing a time of great transition. Digital convergence is making our life ubiquitous. The meaning of "ubiquitous" is "existing or being everywhere at the same time" and the term is used for communication systems where a user can access network resources anytime anywhere with any computer or network. To achieve ubiquitous systems, wired services are coupled to wireless services. That is, high speed internet network, WLAN, 2G & 3G mobile networks are converged to so-called convergence service by which users have access to communication services anytime anywhere. Communication service providers are competitively building hot-spot zones for public places to vitalize convergence service. The following are two major problems from the continuous increase of hot-spot zones. One problem is antenna installations. Installing a multiple antenna causes space shortage, interior degradation, and increasing installation expenses. One solution to this problem is to design a wideband antenna that can cover multiple frequency bands. That is, we need a triple band antenna that covers PCS frequency band (1,850~1,990 MHz/Band class 1), IMT-2000 frequency band (1,920~2,170 MHz), and WLAN frequency band (2,400~2,480 MHz). The other problem is the deterioration of transmission quality caused by terminal interference or multipath fading that usually occurs as multiple terminals are used in the same space and at the same time. This problem occurs especially when WLAN is used and can be resolved by using some specific techniques. Among these techniques reported so far, the polarization diversity is more effective for convergence services. Polarization diversity provides the performance of two antennas with one antenna, and thus it is a space-efficient and cost-effective way.

This study investigates wideband dual-polarized patch antennas to resolve the two problems mentioned above. The main purpose of the study is to design dual-polarized antennas that cover triple bands (PCS, IMT-2000, and WLAN).

2. Feed Structures For Wideband Dual-Polarized Microstrip Antennas

Most researches on microstrip antennas have been focused on methods to extend the bandwidth. It has been reported in the literature in which the broadband characteristics can be obtained by improving the feeding mechanism of microstrip antennas [1]-[3]. Therefore, in this paper, a feeding mechanism was applied that is capable of making wideband by means of reducing the parasitic reactance from the feed structure of the microstrip antenna. We propose a new feeding technique for microstrip antennas that use a pair of L-feeders and aperture coupled feeding mechanism on a single patch as shown in Fig. 1. The wideband operation with an L-feeder is as follows. The antenna proposed in this study includes the inductance (Lc) introduced by the vertical part of L-strip feeder and the capacitance (Cc) between the patch and the horizontal part of L-strip feeder. In other words, the parameters arising from the feeding mechanism are represented by the series Lc-Cc resonant circuit. On the other hand, the equivalent circuit of the patch is represented by the parallel R-L-C resonant circuit as a typical microstrip antenna. Therefore, the series Lc-Cc resonant circuit of the feeding mechanism and the parallel R-L-C resonant circuit act as though they were connected by a serial connection. Consequently, the bandwidth performance of the antenna can be improved by the second resonance caused by the Lc-Cc parameter near the main resonance in the patch. It is especially interesting to note that although the parameter values

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of Lc and Cc in the feeding mechanism are somewhat limited in the single L-strip feeder, they are much more effectively working when a pair of L-strip feeders is used. That is, the inductance and capacitance brought about by the use of a pair of L-strip feeders made it possible to obtain the wide bandwidth characteristics which can more closely approximate the resonant frequency of the TM01 mode of the patch [4].

Fig. 1 shows the geometry of radiating element. The dimensions of feeding mechanism that consists of the patch and a pair of L-strip feeders are optimized by using the CST Microwave Studio [5].

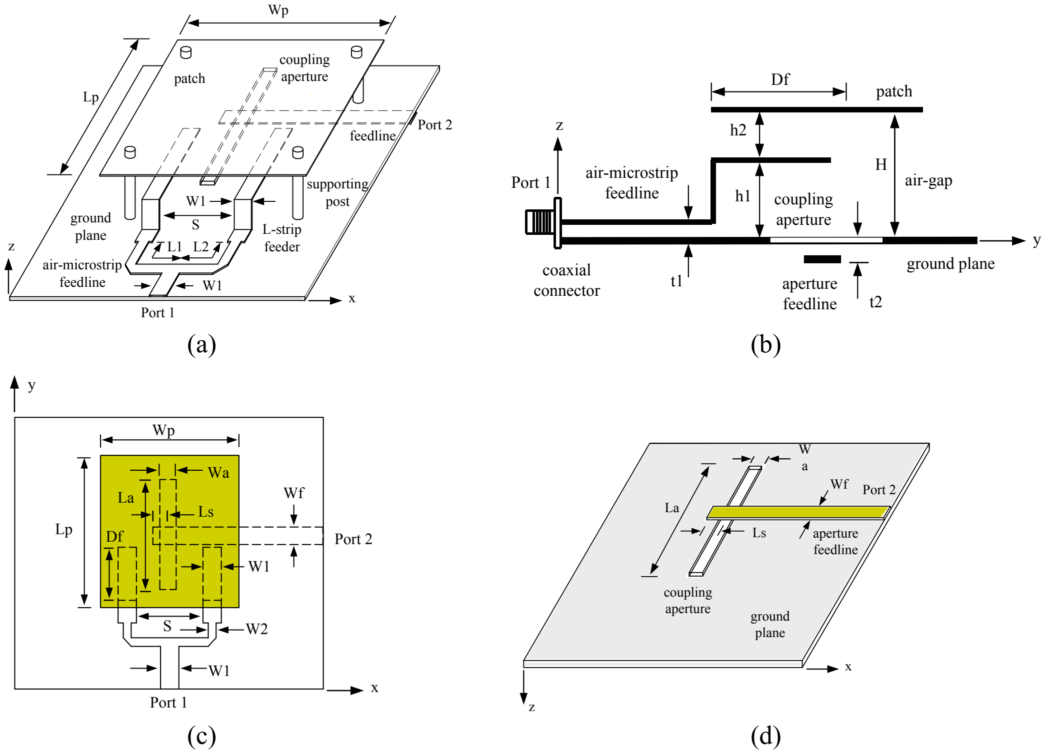
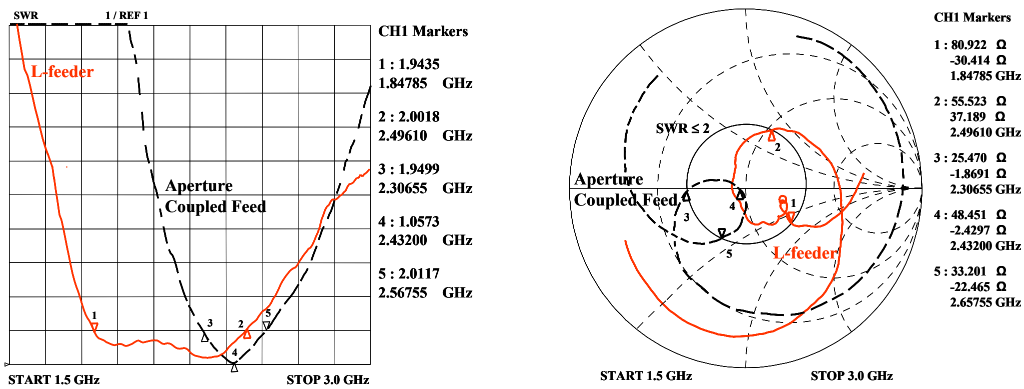


Fig. 1 Geometry of the proposed antenna.

The patch made of thin metal plate of 0.3 mm is supported by the non-metallic post for each of the four edges. The patch is designed to operate at the center frequency (fo=2.165 GHz) for PCS, IMT-2000, and WLAN service band, and the width and length is Wp=66.1 mm (0.477λo) and Lp=52.3 mm (0.377λo). The air-gap, the distance between the patch and the ground plane, is H=23.3 mm (0.168λo). The patch does not contribute to the bandwidth performance of the antenna, however, it does contribute to reducing the size of the patch. Since the proposed antenna uses a pair of L-strip feeders, the feeding mechanism is somewhat complicated. That is why the size reduction of the radiating patch is a prerequisite for the antenna. If the size of patch cannot be reduced, it can be a limiting factor in designing an array. The feeding mechanism of the antenna is made of thin metal plate of 0.3 mm and consists of a pair of L-strip feeders, and the feedline has the structure of what is called an air-gap feedline which does not contain a dielectric substrate. The input and output of feeding mechanism, that is, the feedline (W1) and a pair of L-strip feeders (W1), are designed to match 50 Ω. Since the feedline (W1) is connected to the 50 Ω SMA connector, it is designed for the air-microstrip feedline W1=4.8 mm (50 Ω) and the distance from the ground plane t1=t2=1 mm (not included the metal thickness of feedline and ground plane). The air-microstrip feedline (W1) has a through hole, and the constant height (t1) between the feedline and the ground plane is maintained by using the plastic washer and the screw. The symmetrical power divider with a quarter-wave transformer, L1=L2=36.72 mm (≈0.26λo) and W2=3.1 mm (≈0.02λo), is installed in the area between the feedline (W1) and a pair of L-strip feeders. The vertical and horizontal length of a L-strip feeders are h1=8.3 mm (≈0.06λo) and Df=28.8 mm (0.2λo), respectively. And, the distance between the two L-strip feeders is S=27.3 mm (0.197λo). Aperture-coupled feed is another type of electro-magnetically coupled feed that is studied in this paper. It is a feeding mechanism where electromagnetic flux from the feedline is concentrated to an aperture, which is passed to a patch. This type of feeding mechanism generates unwanted radiation by the feedline. The location of the feedline, however, can be directed in an opposite direction by the ground plane and isolated and thus the radiation pattern of the antenna is not affected much. For the dielectric substrate that is in the opposite direction to the patch based on the ground plane, different dielectric constant materials can be used if needed. The polarization characteristics can be realized in a variety of ways depending on the location of the aperture and multiple resonant frequencies can be used [6],[7]. This study proposes a new feeding structure that can make good isolation and manufacturing cost minimization as shown in Fig. 1. Aperture coupled feed is designed as an air-gap feedline that is the same as the feeding mechanism by L-feeders. The structure of the microstrip antenna illustrated in Fig. 1 shows that the feedline of port 1 passes equal magnitude and phase to a pair of L-feeders and coupled to the patch while the other feedline of port 2 is coupled to the patch through the aperture. In this structure, the choice of the feedlines (port 1 or port 2) operates as an antenna for vertical polarization (E_V) and horizontal polarization (E_H). To obtain the characteristics of wide impedance bandwidth and low cross polarization, the aperture is located at the center of the patch, and the L-feeders are located symmetrically with reference to the aperture, which reduces coupling with the aperture and suppress odd-mode excitation. The relevant length and width of the aperture slot are 0.1~0.2λg and 0.01~0.02λg respectively. The length of the slot and the stub can be adjusted for impedance matching. As the stub length increases, the impedance locus rotates in a clockwise direction along a constant resistance circle. As the stub length approaches a quarter-wavelength long, the impedance curve crosses the real axis of the Smith chart. The stub length is adjusted until the impedance at the design frequency is purely real. The microstrip antennas with a pair of L-feeders and that with an aperture coupled feed type are shown in Fig. 1 (c) and (d), respectively. The two feeding mechanisms are integrated but they are operated independently as vertical polarization (E_V) and horizontal polarization (E_H) antennas.

3. Measurement Results and Discussion

The measurements of the SWR and the impedance plot of the microstrip antennas with a pair of L-feeders and that with an aperture coupled feed type are shown in Fig. 2 (a) and (b), respectively. The impedance bandwidth (SWR≤2) of the microstrip antennas with a pair of L-feeders is 33.24 % (1.848~2.496 GHz) at fo=2.165 GHz, and that of the aperture coupled feed antenna is 10.7 % (2.31~2.568 GHz) at fo=2.44 GHz. As shown in Fig. 2, the impedance locus of the proposed antenna is mostly included inside the circle expressed as the condition of SWR≤2.



(a) (b)

Fig. 2 Measured SWR and Smith chart plot.

Fig. 3 represents the decoupling degree between these two ports, S21, which is below –30 dB in the frequency range between 1.5~3.0 GHz. The most sensitive parameters of the proposed antenna are the length (Df), the height (h1) of L-strip, and the height of the air-gap (H). This means that the coupling values of the patch and a pair of L-strip feeders are relying on these parameters. On the other hand, the distance (S) between the two L-strip feeders did not affect the characteristics of the antenna to a great extent. We found from these parameters that the gain keeps increasing as the air-gap (H) decreases, but that the bandwidth is reduced because of impedance mismatching. To sum up, the length of the L-strip feeder (Df) and the height of the air-gap (H) are important factors directly influencing the gain and impedance bandwidth of the antenna. It is not feasible to design both the gain and the impedance bandwidth of the antenna simultaneously at the maximum condition. One or the other should be selected as a trade-off. Fig. 4 shows the prototype of the proposed antenna. The structure of the antenna is designed for the air-gap structure rather than dielectric substrate, its manufacturing processes are simplified. Thus, the antenna is capable of reproducing its uniform characteristics in the mass production process. Fig. 5 shows the radiation patterns measured at 1.85 GHz. The radiation patterns are stable. The H and E-plane 3dB-beamwidth of the L-strip fed patch at the frequency of 1.85 GHz is respectively 80.03° and 64.92°, and the aperture coupled patch show 78.2° and 73.4° respectively. Fig. 6 shows radiation patterns measured from an aperture coupled feed antenna at 2.44 GHz that is the central frequency of WLAN services. The gain increases as the frequency increases in both cases of the L-strip fed patch and aperture coupled patch. The peak gain of the L-strip fed patch is 8.44 dBi (at 2.11 GHz) and 7.75~8.44 dBi cross the passband. And, the peak gain of the aperture coupled patch is 7.12 dBi (at 2.46 GHz) and 6.72~ 7.12 dBi cross the passband. The proposed antenna had the impedance bandwidth of about 3 % larger than that of the reported antenna, and the maximum gain was nicely obtained by 8.44 dBi that is about 0.9 dBi higher than that of the reported antenna [4].

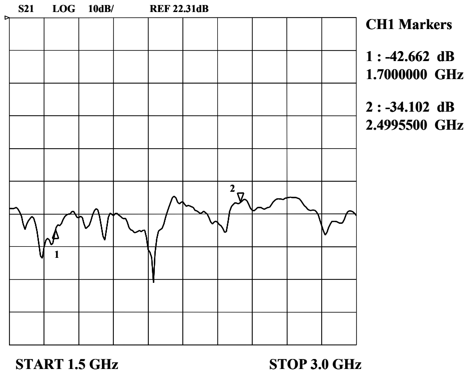


Fig. 3 Measured isolation between two ports.

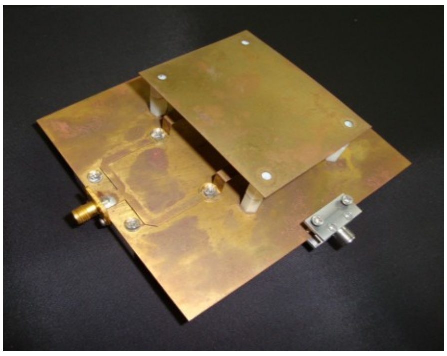
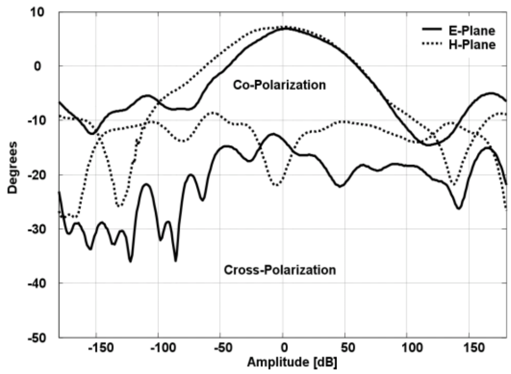


Fig. 4 Photograph of the antenna proto-type.



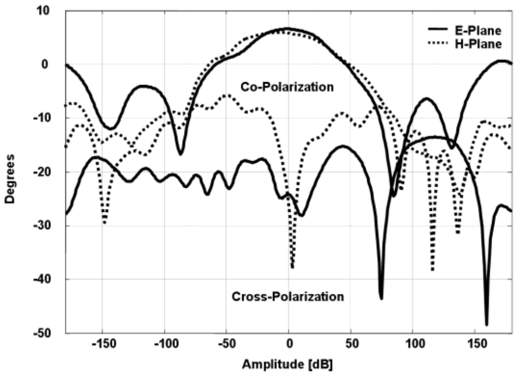


Fig. 5 Measured radiation patterns of L-strip fed antenna. Fig. 6 Measured radiation patterns of aperture coupled patch.

4. Conclusion

The antenna proposed in this study is expected to present a variety of commercial applications by designing it further as triple band (PCS, IMT-2000, and WLAN) antennas. Also, the structure of this antenna can be modified as an air-gap feedline type that does not use a dielectric substrate, which will simplify its manufacturing processes and realize uniform its quality for mass production. Another advantage is that this antenna can be used for base stations that use high power. The proposed antenna is characterized as vertical and horizontal polarization from two ports. It can cover triple service band (PCS, IMT-2000, and WLAN) and especially for WLAN services, this antenna is expected to prevent the deterioration of transmission quality caused by terminal interference or multipath fading.

5. References

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