variation over time. This Letter shows how to construct a representative statistical sample that accounts for both short-term and long-term variation of electrical parameters from the component population. The measured data of statistically represented inductors and capacitors are used in demonstrating first-pass design success of an LC filter, involving SMD components with appropriate layout footprint and interconnects implemented in a CPW environment.

Statistically rank-ordering the component traces enables two important facets of CAD simulation packages: optimization and yield analysis. A circuit can be visualized as a system of interconnected data files representing the measured components. The component's data that closely match the median value from all the measurements can be used for optimization of the circuit. The remaining data, randomly selected from the component's overall population, may be used in a Monte Carlo yield analysis. Thus, using the approach presented, CAD simulators can now optimize circuits based on component's measured data, which accounts for the statistical variation (tolerance, etc.), layout and package parasitic effects. Designers may then more effectively correlate CAD simulation with prototype builds, resulting in a reduction of design cycle time.

REFERENCES

1. D.D. Jatkar and B. Becker, Effects of package parasitics on the performance of SAW filters, IEEE Trans Ultrason, Ferroelectrics Freq Control. 43(1996), 1187–1194.
2. G.A. Hjellen, Including dielectric loss in printed circuit models for improved EMI/EMC predictions, IEEE Trans Electromagn Compat EC-39 (1999), 236–246.
3. K. Naishadham, Closed-form synthesis of equivalent circuits incorporating package-induced parasitics, IEEE International Microwave Symposium Digest, Phoenix, AZ, May 2001.
4. M.D. Meehan, R. Spence, and J. Purviance, Yield and reliability in microwave circuit and system design, Wiley, New York, 1993.
5. G. Keppel, Design and analysis—A researcher's handbook, 3rd ed., Prentice Hall, Upper Saddle River, NJ, 1991, pp.71–86.
6. JMP™ Statistical Analysis Software, SAS Institute Inc., 2000 (www.JMPdiscovery.com).
7. J.R. Juroshek, C.M. Wang, and G.P. McCabe, "Statistical analysis of network analyzer measurements, Cal Lab, Int J Metrol, 1998, 26–31.
8. N.A. Weiss and M.J. Hasset, Introductory statistics, 2nd ed., Addison-Wesley, Reading, MA, 1987, pp. 56–61.

A DUAL-BAND GPS MICROSTRIP ANTENNA

Chih-Ming Su and Kin-Lu Wong
Department of Electrical Engineering
National Sun Yat-Sen University
Kaohsiung 804, Taiwan

Received 26 October 2001

ABSTRACT: *Design considerations and experimental results of a dual-band circularly polarized stacked microstrip antenna for GPS operations at 1227 and 1575 MHz are presented. The antenna is achieved by stacking two corner-truncated square microstrip patches. The obtained circular polarization (CP) bandwidths, determined from 3-dB axial ratio, are about 15 MHz (about 1.2%) and 17 MHz (about 1.1%) at 1227 and 1575 MHz, respectively. Good CP radiation patterns and antenna gain have also been observed.* © 2002 Wiley Periodicals, Inc.

Microwave Opt Technol Lett 33: 238–240, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.10285

Key words: *microstrip antennas; GPS antennas; circularly polarized antennas*

1. INTRODUCTION

Because of their low-profile advantage, circularly polarized microstrip antennas are very attractive for global positioning system (GPS) applications. However, many of the related designs available in the open literature, operate at the GPS band at 1575 MHz only. Very few designs can cover the two GPS bands at 1227 and 1575 MHz, which is necessary in more demanding operations, such as those requiring differential GPS operation [1].

To achieve GPS operations at 1227 and 1575 MHz, microstrip antennas should perform dual-band circularly polarized radiation [2]. For designs using single feed only, there are generally two kinds of microstrip antennas capable of dual-band CP radiation: one uses a single patch [3, 4] and one uses two stacked patches [5, 6]. For single-feed single-patch designs, the ratio of the two CP operating frequencies is reported to be about 1.5 or larger [3, 4], which makes it less promising for achieving two GPS operations at 1227 and 1575 MHz (their frequency ratio is about 1.28 only). On the other hand, the two CP operating frequencies of the single-feed stacked-patch designs usually have a ratio less than 1.5 [5, 6], which makes it possible to cover the two GPS bands at 1227 and 1575 MHz.

This article demonstrates a successful single-feed dual-band CP design using two stacked patches for achieving CP operations at 1227 and 1575 MHz. The total antenna height is less than 4 mm,

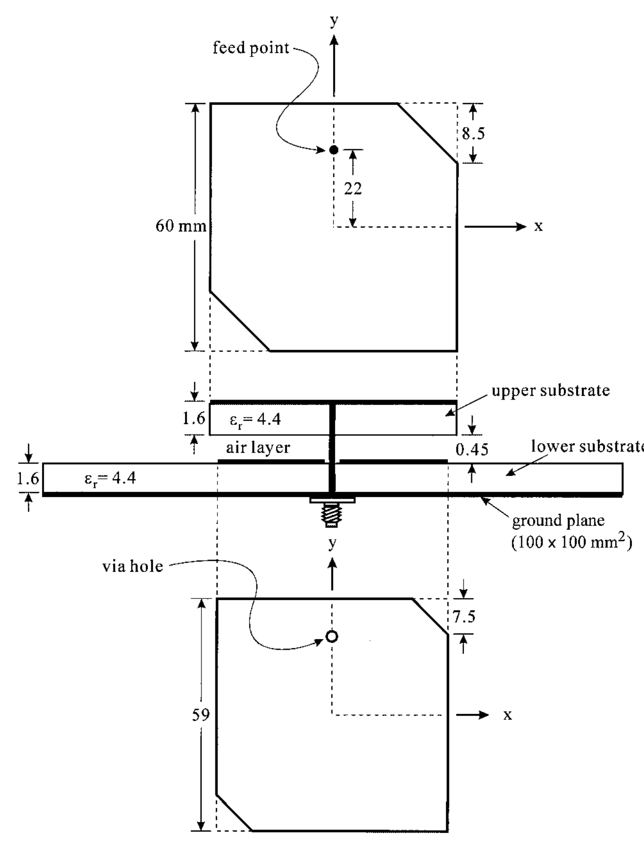

Figure 1 Geometry of the proposed dual-band microstrip antenna for GPS operations at 1227 and 1575 MHz

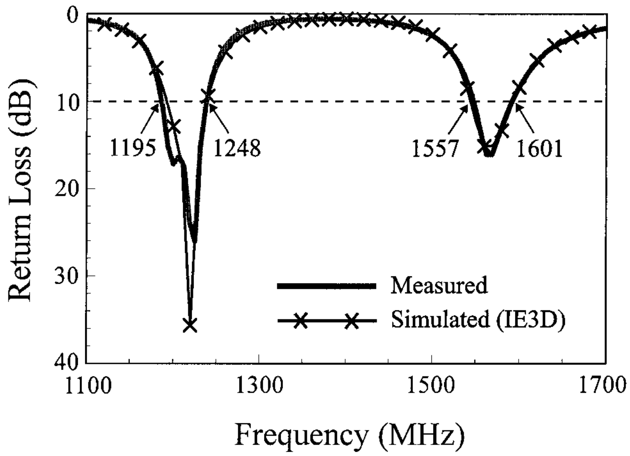

Figure 2 Measured and simulated return loss of the proposed antenna

much smaller than that (>12 mm) of a dual-band CP design using the two-feed method [1]. Details of the design and testing of the proposed antenna are presented.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed design for achieving CP operations at 1227 and 1575 MHz. Two stacked corner-truncated square patches are printed on inexpensive FR4 substrates of thickness 1.6 mm and relative permittivity 4.4, and a probe feed excites the upper patch through a via hole in the lower patch.

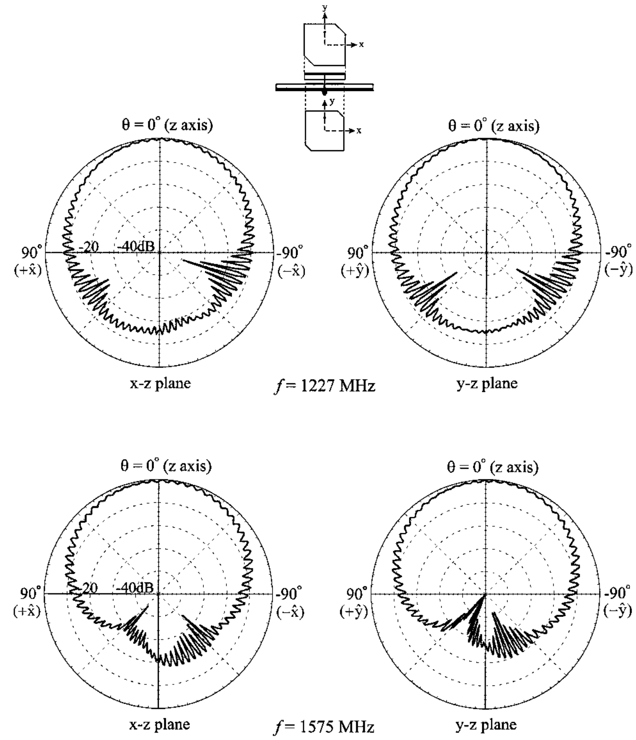

Figure 4 Measured spinning linear radiation patterns of the proposed antenna at 1227 and 1575 MHz

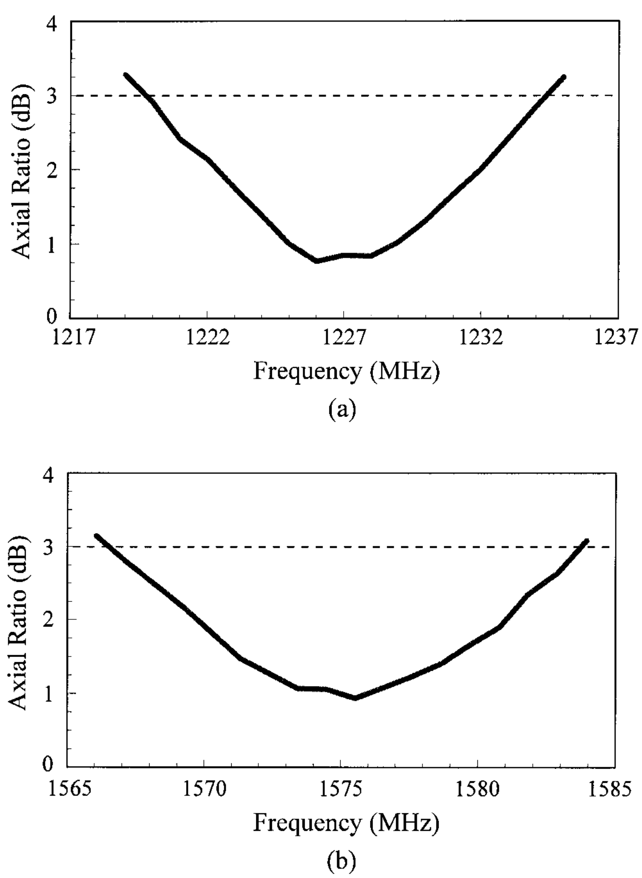

Figure 3 Measured axial ratio in the broadside direction of the proposed antenna. (a) Lower band, (b) upper band

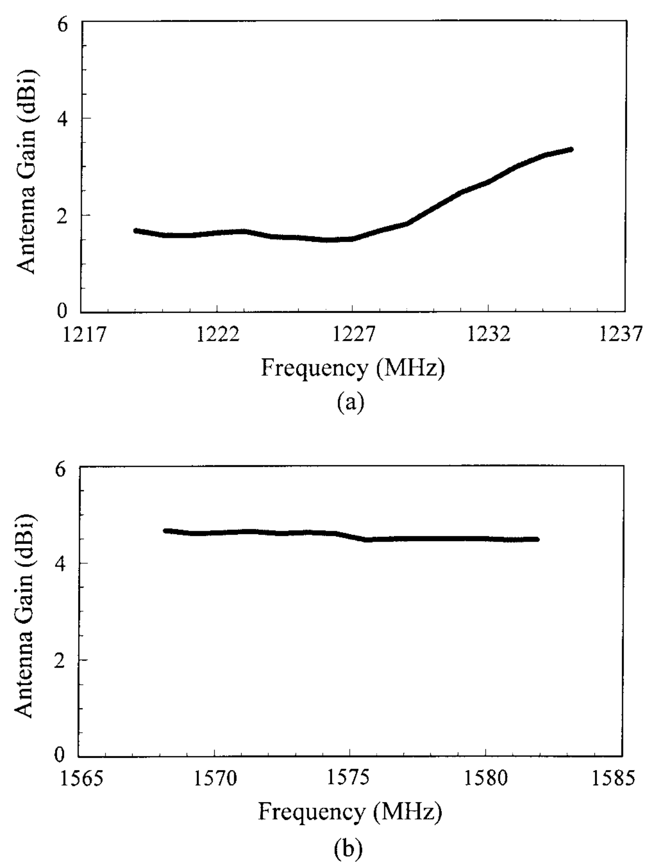

Figure 5 Measured antenna gain of the proposed antenna. (a) Lower band, (b) upper band

Between the upper and lower patches, there is also a thin air layer. By varying the air-layer thickness, the frequency ratio of the two CP operating frequencies can be varied. In Figure 1, the designed dimensions are given, which are obtained with the aid of the commercially available simulation software IE3D. Notice that, for the dual-band designs using stacked patches [5], the sizes of the two patches are mainly determined by the lower of the two operating frequencies (i.e., 1227 MHz in this design). That is, the resonant lengths of the two square patches should be about the same, but not equal, and greatly depend on the lower CP frequency at 1227 MHz. In addition, in order to successfully excite an additional (upper) CP frequency at 1575 MHz in the present design, it is required that the resonant length of the upper patch be larger than the lower one.

Following the above design considerations for the proposed antenna, the size of the lower patch is selected to be 59×59 mm^2, whose two opposite corners with a side length of 7.5 mm were also truncated in order to achieve CP operation at the desired frequency 1227 MHz. Then another CP operation at the desired frequency 1575 MHz was obtained by selecting the size of the upper patch to be 60×60 mm^2, the side length of the truncated corners to be 8.5 mm, and the thickness of the air layer to be 0.45 mm.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed antenna has been constructed and studied. Figure 2 shows the measured and simulated return loss. Very good agreement between the measurement and the simulation is seen. For the lower band, the obtained impedance bandwidth, determined from 10-dB return loss, is 53 MHz, or about 4.3% with respect to 1227 MHz. For the upper hand, the impedance bandwidth is 44 MHz, or about 2.8% referenced to 1575 MHz. Measured axial ratio in the broadside direction for the lower and upper bands is presented in Figure 3. The obtained CP bandwidths, determined from 3-dB axial ratio, cover both desired CP operating frequencies 1227 and 1575 MHz. The CP bandwidths of the lower and upper bands reach about 15 MHz (about 1.2%) and 17 MHz (about 1.1%), respectively.

Figure 4 shows the measured spinning linear radiation patterns at 1227 and 1575 MHz. Good broadside CP radiation patterns are seen. Figure 5 presents the measured antenna gain in the broadside direction for the lower and upper bands. The measured antenna gains for 1227 and 1575 MHz are about 1.5 and 4.5 dBi, respectively.

4. CONCLUSIONS

A stacked microstrip antenna suitable for dual-band GPS operations at 1227 and 1575 MHz has been presented. The antenna has a low profile (less than 4 mm) in appearance and is inexpensive to construct because of the inexpensive FR4 substrates used. The antenna also shows good CP radiation characteristics at the two GPS operating frequencies.

REFERENCES

1. D.M. Pozar and S.M. Duffy, A dual-band circularly polarized aperture-coupled stacked microstrip antenna for global positioning satellite, IEEE Trans Antennas Propagat 45 (1997), 1618–1625.
2. K.L. Wong, Compact and Broadband Microstrip Antennas, Wiley, New York, 2002, Chap. 9.
3. K.P. Yang and K.L. Wong, Dual-band circularly polarized square microstrip antenna, IEEE Trans Antennas Propagat 49 (2001), 377–282.
4. K.B. Hsieh, M.H. Chen, and K.L. Wong, Single-feed dual-band circularly polarized microstrip antenna, Electron Lett 34 (1998), 1170–1171.
5. J.Y. Jan and K.L. Wong, A dual-band circularly polarized stacked elliptic microstrip antenna, Microwave Opt Technol Lett 24 (2000), 354–357.
6. B. Balakrishnan and G. Kumar, Dual band circularly polarized off-centered EMCP antennas, in IEEE Antennas Propagat Soc Int Symp Dig, 1998, pp. 316–319.

LONG-WAVELENGTH EDFA GAIN ENHANCEMENT THROUGH 1550-nm-BAND LASING

Junqiang Sun
Department of Optoelectronic Engineering
Huazhong University of Science and Technology
Wuhan 430074
Hubei, P. R. China

Received 9 November 2001

ABSTRACT: *Gain enhancement and bandwidth broadening in a long-wavelength band (L band) EDFA are demonstrated by incorporating an erbium-doped fiber laser. Utilizing the strong 1550 nm lasing signal used as a secondary pump source, considerable improvements in gain and its bandwidth are achieved. The enhancement of the L-band gain characteristics is strongly influenced by a secondary pump signal wavelength and its optical power.* © 2002 Wiley Periodicals, Inc. Microwave Opt Technol Lett 33: 240–242, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.10286

Key words: *long-wavelength band; gain enhancement; bandwidth broadening; erbium-doped fiber amplifiers*

1. INTRODUCTION

Versatile erbium-doped fiber amplifiers (EDFAs) can offer extremely broad gain bandwidth ranging from 1530 nm up to 1600 nm and beyond [1]. Such broad gain bandwidth can be applied in dense wavelength division multiplexed (DWDM) transmission systems to compensate for the fast bandwidth consumption [2]. Although the L-band (1570–1600 nm) gain spectrum is intrinsically flat, unfortunately, L-band EDFAs are relatively inefficient due to the operating wavelengths that are far from the peak emission. In order to improve gain characteristics in this band, several approaches have been proposed. The use of new material composition for the fiber with various structural parameters, such as silica-based EDFAs [3], enables high gain in the L band to be implemented with shorter erbium-doped fiber lengths. Detrimental backward amplified spontaneous emission (ASE) was utilized as a secondary pump source for the unpumped EDF sections which caused a gain increment in the L band [4]. Reflecting a small fraction of the ASE back into the EDFA suppressed the ASE losses and increased the L-band gain [5]. This Letter demonstrates a novel, highly efficient EDFA structure for L-band signal amplification, in which a tunable erbium-doped fiber-ring laser is included. The 1550-nm band lasing is employed as the secondary pump source for the EDFA. Experimental results show that EDFA ASE spectrum bandwidth is broadened up to 1635 nm. The gain characteristics are greatly improved.

2. EXPERIMENTAL SETUP

The experimental arrangement of the L-band operation EDFA is shown schematically in Figure 1. A 15-m-long EDF is pumped by a 980-nm laser diode with a maximum power of 80 mW through a 980/1550-nm WDM fiber coupler. The laser-ring cavity is com-