Comment and Reply

Comments on "Wide-Band E-Shaped Patch Antennas for Wireless Communications"

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In the July 2001 issue of IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, a paper entitled "Wide-Band E-Shaped Patch Antennas for Wireless Communications" was published by Yang *et al.* [1]. In the paper, the authors presented an E-shaped microstrip antenna stating that it is a "novel" antenna for wireless communications. Seven years ago, the author of this correspondence invented this antenna in 1994 for Nokia Mobile Phones when he was their Director of Antenna Engineering. The antenna was called the "Double C-patch Antenna" and includes the "E-shaped Antenna" as a special case of its several configurations. Double C-patch antennas were developed, analyzed, studied, manufactured, tested, optimized, and then published, for the first time, in Proceedings of the IEEE AP-S Symposium in 1995 [2]. Since then, a number of developments and modifications were added to the double C-patch antenna and it has been used in several applications at Nokia Mobile Phones (see [3]–[5], for example). Also, several wireless communication publications have referred to double C-patch antennas such as the *Microwave Journal* papers [6], [7], which are used all over the world as the basis of internal integrated antennas for portable wireless communication equipment. Furthermore, in 1995 Nokia Mobile Phones filed a patent application for this antenna under the name of Mohamed Sanad, the author of this correspondence. The patent was granted in 1997 [8]. Two other patents for different configurations and applications of double C-patch antennas were granted for Nokia Mobile phones in 1997 [9], [10]. The geometry of the preliminary configuration of "double C-patch antennas" with rectangular aperture shapes as it appeared in [2] and [8]–[10] and the "E-shaped patch antennas" shown in the July 2001 paper are identical. However, the published research and development on double C-patch antennas went far beyond the preliminary antenna configuration that was published in the July 2001 paper. Thus, the E-shaped antenna is only one of several patented configurations and applications of the double C-patch antenna [2]–[10].

Double C-patch antennas were short-circuited between their apertures in order to reduce their size [2]–[8]. Shorted double C-patch antennas having different aperture shapes were integrated into PCMCIA communication cards and wireless modems [4]–[8]. In order to increase the bandwidth of double C-patch antennas without increasing their dimensions significantly, narrow parasitic double C-patch elements were gap-coupled to a directly fed narrow double C-patch element [5]–[8]. To further increase the bandwidth of double C-patch antennas, both stacked and planar parasitic double C-patch elements have been used simultaneously [10]. A modified version of this antenna concept was optimized, shielded, and used as an internal integrated antenna for PCS (1850 to 1990 MHz) and cellular phones (825 to 895 MHz) in order to replace their external antennas. With a dielectric constant of about 6, the total size of the cellular phone internal antenna configuration, including the ground plane, was about $30 \times 30 \times 3$ mm [6]. Compact dual-band antennas were designed for different combinations of mobile communications. In these applications, it is advantageous to cover both frequency bands by an antenna having two well-separated bands (rather than one wide continuous band) where the antenna can work as the first stage of filtering. For example, an internal integrated dual band antenna having two separated bands for portable GPS/cellular phones was developed by adding a third thin layer (1 mm thickness) to the above compact cellular antenna configuration [7].

Manuscript received August 15, 2001; revised September 6, 2001.

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Digital Object Identifier 10.1109/TAP.2002.807369

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[10] ——, "Wideband stacked double C-patch antenna having gap-coupled parasitic elements," U.S. Patent 5 680 144, Oct. 21, 1997.

Authors' Reply

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In the paper cited [1], we regret that we did not refer to Dr. Sanad's work published in conference proceedings and trade journals, and thank him for his interest in our paper. We have reviewed all the reference papers that Dr. Sanad mentioned, especially [2] and [3], and it is clear that Dr. Sanad has done a lot of work on the double C-patch antennas.

Manuscript received November 8, 2001.

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Digital Object Identifier 10.1109/TAP.2002.807366

Although Sanad's double C-patch antennas and our E-shaped antenna are similar in geometrical configurations, their RF operating mechanisms are vastly different. The wide-band E-shaped patch excites the horizontal mode of the patch and the slots are parallel to the mode while the double C-patch excites the vertical mode and the slots are vertical to the mode, as shown in Fig. 1. Because of the different operating modes, the antennas have characteristically different features. The E-shaped patch antenna exhibits a wide bandwidth of over 30%, while its size is similar to normal patch antennas. The double C-patch antenna has a relatively compact size while its bandwidth is similar to normal patch antennas. To demonstrate the points above, the E-shaped patch antenna and the double C-patch antenna are contrasted in following aspects.

1) *Feeding position*

   Fig. 1 displays both the vertical and horizontal central lines of the patch.

   The E-shaped patch: The feeding probe is located on the horizontal central line so that it will activate the horizontal mode and block the vertical mode.

   The double C-patch: The feeding probe cannot be located on the horizontal central line since it is the "zero potential plane" for the double C-patch antenna. Instead, it is located on the vertical central line. As stated in [2], "The shorted double C-patch antenna is fed between the aperture and the shorted edge on the central line of the antenna which passes through the center of the shorted edge."

2) *Radiating edges*

   The E-shaped patch: The left and right edges are radiating edges.

   The double C-patch: The top and bottom edges are radiating edges.

3) *Radiation pattern and polarization*

   The E-shaped patch: The antenna radiates to boresight and it is only sensitive to one polarization.

   The double C-patch: As stated in [2], "the antenna is sensitive to both polarizations and the radiation patterns are quasi-isotropic."

4) *Impedance bandwidth*

   The E-shaped patch: This has a much wider bandwidth than a normal patch antenna. It achieves a bandwidth of over 30% using a single-patch element.

   The double C-patch: Even though it uses parasitic patches, the bandwidth is less than 6% ($S11 < 10$ dB criterion) according to [3, Fig. 2]. In [4], both gap coupled and stacked parasitic patches are employed and the bandwidth is "equal to or greater than approximately 70 MHz at a frequency of approximately 850 MHz." So its bandwidth is still less than 10%.

5) *Antenna size*

   The E-shaped patch: This has a similar size as the normal half-wavelength patch.

   The double C-patch: As stated in [3], "the size of each partially shorted double C-patch element is less than 25% of the size of the conventional half wavelength rectangular microstrip antenna."

   From the comparison, it is clear that although our E-shaped patch antenna bears some geometrical configuration similarities with the double C-patch antenna, its radiating characteristics and applications are completely different. Therefore, we presented the E-shaped patch antenna as a novel *wide-band* microstrip antenna.

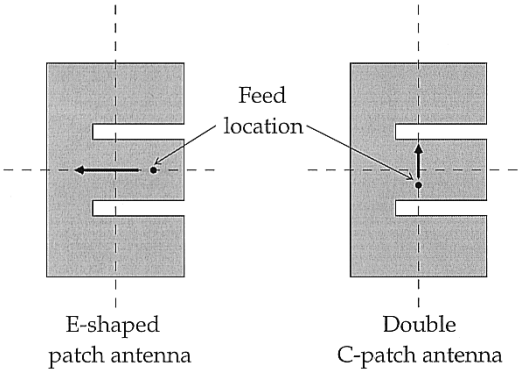

Fig. 1. Comparison of the wide-band E-shaped patch antenna and the double C-patch antenna. Note that the feed locations and the operating modes are totally different.

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