A small, compact and single-fed CP stacked patch was presented to cover all GPS bands. A key feature of this design is the integrated branch-line hybrid, which achieves CP excitation for the stacked patches. The small aperture size (\(\lambda/8\) at L5/1176 MHz) and single feed property makes this antenna quite attractive for small GPS arrays. The design was verified with measurements. Also, the final hybrid design was adjusted for reduced coupling when placed in an array setting.

**IV. CONCLUSION**

A prototype has been manufactured and measured. The measurements, that match the design objectives, are also presented.

**REFERENCES**


In general, the design of a patch having high isolation results in antennas with narrow bands or high values for return losses (RL). For example, in [1] and [3] bandwidths from 17.2% to 21% with isolations from 30 to 36 dB are found considering —10 dB for return losses. The antennas presented in [2] and [4] show high values of matching level (RL < —20 dB) and isolation (35 dB), in a band of 100 MHz at 7.7 GHz in [2] and from 1.85 GHz to 1.99 GHz in [4].

The antenna proposed in [7] has a 52% bandwidth for isolation values of 39 dB at —10 dB return loss. This matching level is useful for many applications but it is not advisable to design arrays for base station antennas. Besides, the solution proposed in [7] uses two layers (and boards) for the input signals, while the antenna has the input lines in the same layer of the same board. The use of two layers increases the complexity and mainly the cost since, it is known, RF substrates and the etching drive to ones of the most important contributions in the antenna cost.

On the other hand, when high bandwidths for high matching levels are obtained, the isolation performances degrade. In [8] an antenna with a bandwidth greater than the 20% for return losses of —14 dB shows isolation greater than 25 dB.

This communication proposes a dual polarization patch antenna having high matching level and high isolation between polarization on the same element that make it suitable for array antenna implementation. The design considers the bandwidth specification for return losses and isolation, with targeted values of —22 dB and 33 dB, respectively for the two ports of the same element in the band as prototype aims. Therefore, this communication proposes a geometry that simultaneously reaches large bandwidths with a low level of isolation simultaneously. The main innovation of this communication is founded in the geometry of the slot which is shaped with a narrow central part to keep the high isolation values and a wider part to obtain high coupling between the lines and the patches to allow high matching level in a wide band.

It also addresses other critical specifications that would allow it to be used as radiating element of a base station antenna; coupling between elements and back radiation. The designed radiating element is a two-stacked patch antenna, which is fed to the input microstrip line by means of a slot. The simulations show that the main goals are matched.

A prototype and its measurements are also presented, showing that the main challenges of the design: low return losses and high isolation between ports in a 25% band have been overcome in this case.

### II. SPECIFICATIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design</th>
<th>Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>1.690 MHz—2.190 MHz</td>
<td>1.710 MHz—2.170 MHz</td>
</tr>
<tr>
<td>Return Loss</td>
<td>&lt; —23 dB</td>
<td>&lt; —20 dB</td>
</tr>
<tr>
<td>Coupling Between Ports</td>
<td>&lt; —36 dB Typical</td>
<td>&lt; —33 dB Typical</td>
</tr>
<tr>
<td>Front to back ratio</td>
<td>&gt; 25 dB</td>
<td>&gt; 25 dB</td>
</tr>
</tbody>
</table>

The specified isolation between ports for antenna arrays is typically about 30 dB. This is a very stringent requirement, and even using some compensation techniques in the array design, to reach this value, the isolation between the ports in the element used has to be better, the array design being simpler as this value is improved.

### III. ANTENNA ARCHITECTURE AND DESIGN

It is well known that the aperture-coupled patch is the configuration that results in greater bandwidths. This is essential in this antenna because of the band requirement. The input line is a microstrip located on the back plane. Fig. 1 shows the general antenna architecture, which is discussed in more detail in the following sections. Fig. 2 shows the top view of conductors and an indication of the coordinate system.

#### A. Patches and Substrate

In order to achieve the matching bandwidth, two stacked patches with thick substrate are needed. Many references on stacked patches can be found; representative of them are [9]—[11]. Patches on high dielectric constant substrates have a lower bandwidth than patches on low dielectric constant substrates. As a consequence of this, it could be that the best substrate is air (in fact a patch printed on any dielectric with an air space). However, increasing the patch substrate dielectric constant reduces back radiation and reduces coupling between patches in an array, which are important requirements in this application. Therefore, to select the dielectric constant a trade-off has to be made. It was
found that a very appropriate value for the dielectric constant was in the range of 1.5–1.8. The material used in this design was Expanded PVC with a measured dielectric constant of 1.65 and delta tangent of 0.0035. This material has already been used in linear polarized patches for this application in [12].

Since a dual polarization with the same requirements is sought, the patches are squared.

To reduce costs, the patches are printed directly onto the substrate.

B. Slots

Because a large bandwidth is required and the patch substrate is thick, large coupling between the lines and the patches is needed. It is known that the centered slot configuration is the one that yields the greater coupling. So the two slots needed for a dual polarization antenna cross in the center. This solution consisting of crossing the slot has been already used as discussed in the introduction.

A dual slot configuration with one of the slots displaced from the center (offset slot) was researched, however the bandwidth and coupling requirements were not found, as it had features quite far from those specified.

Even with the centered slot configuration, the resulting slots in the first approach had large widths yielding very high coupling values in the specified band. The solution to achieving the bandwidth and coupling requirement was found by using a slot that has a wide width in the outer part of it, and narrow width in the inner part as can be seen in Figs. 1, 2, and 3. In addition, this allows a single polarization design, using the common design criteria for patch antennas and then it is only necessary to add the second polarization slot.

C. Input Lines and Substrate

To keep losses as small as possible, a high quality RF substrate has been used. The selected substrate was Arlon AD-320. It has a DK of 3.2 and a loss tangent of 0.003. The height of this substrate is 0.8 mm. Each slot is fed by a couple of microstrip lines over the wide part of the slot. These lines end in an open circuit having been the length of these sections chosen to compensate the inductance found at the resonance frequency.

The lines for both polarizations are printed on the same face of the board. To avoid line crossing, the open-ended line sections are bent as can be seen in Fig. 2. The impedance of these lines was selected at 80 \( \Omega \). A T-junction is used to go from the single input line to these lines, therefore the input line impedance is 40 \( \Omega \) to allow the division. Since the input port impedance was set to 50 \( \Omega \), a quarter wavelength section is introduced to change from 50 \( \Omega \) to 40 \( \Omega \).

D. Air Bridge

Using the two input lines and bending them at the end, just one line cross is found. This cross cannot be avoided, so an air bridge was included in one of the lines. Because a very high isolation is desired, the bridge has to add as low a coupling as possible. To reduce the line coupling, the microstrip line has been narrowed; therefore the added inductance has been compensated by a capacitance load as can be seen

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**Fig. 3.** Antenna geometry parameters. (a) Patches. (b) Slots. (c) Slot center detail. (d) Input lines. (e) Input lines stub. (f) Bridge detail.

**TABLE II**

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Dielectric constant</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper patch substrate</td>
<td>Expanded PVC</td>
<td>1.65</td>
<td>18.0</td>
</tr>
<tr>
<td>Lower patch substrate</td>
<td>Expanded PVC</td>
<td>1.65</td>
<td>12.0</td>
</tr>
<tr>
<td>Microstrip substrate</td>
<td>Arlon AD320</td>
<td>3.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Back Spacer</td>
<td>Air</td>
<td>1.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Back board</td>
<td>FR4</td>
<td>4.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**TABLE III**

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper patch length and width</td>
<td>Up-Wl</td>
<td>38.32</td>
</tr>
<tr>
<td>Lower patch length and width</td>
<td>Lp-Wl</td>
<td>44.38</td>
</tr>
<tr>
<td>Slot length</td>
<td>Sl-L</td>
<td>37.20</td>
</tr>
<tr>
<td>Inner Slot length</td>
<td>Sl-La</td>
<td>9.00</td>
</tr>
<tr>
<td>Narrower slot section length</td>
<td>Sl-Lb</td>
<td>3.00</td>
</tr>
<tr>
<td>Slot width</td>
<td>St-W</td>
<td>4.80</td>
</tr>
<tr>
<td>Inner slot width</td>
<td>St-Wa</td>
<td>0.80</td>
</tr>
<tr>
<td>Narrower slot width</td>
<td>St-Wb</td>
<td>0.50</td>
</tr>
<tr>
<td>Bent stub length</td>
<td>St-L</td>
<td>4.87</td>
</tr>
<tr>
<td>First stub section position</td>
<td>St-P</td>
<td>5.52</td>
</tr>
<tr>
<td>Input lines separation</td>
<td>L-S</td>
<td>19.20</td>
</tr>
<tr>
<td>Input lines width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input port line length</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dual polarisation element simulations

in Fig. 2 and Fig. 3(f). A similar situation is found in the bridge, since it has been implemented by a long wire that behaves as an inductor.

E. Back Scatterers

To reach the required back radiation specifications, a front to back (F/B) ratio greater than 25 dB, back scatterers printed on FR4 were introduced at a distance of 25 mm. By using them, the obtained F/B ratios in simulation were 26.8 dB at 1.7 GHz and 30.2 dB at 2.2 GHz, while the F/B ratio obtained without the reflectors were 14.2 dB and 18.8 dB at 1.7 GHz and 2.2 GHz, respectively. This solution is very similar to that used in [13] for aperture coupled patches with single polarization. It was applied in [14] to cancel the back radiation in coplanar fed patches with dual polarization. The results presented in [14] show that these scatterers are a good solution to cancel the back radiation in antenna configurations with single-feed dual-polarization, but it is stated that some reduction of the improvement was found at certain frequencies when used in dual-polarization antenna configurations with dual-fed, coplanar lines.

The results obtained in the prototype presented in this communication, which are very similar to those presented in [12], show that these scatterers are useful for antenna configurations of dual-feed, dual-polarization using microstrip lines.

F. Complete Geometry Parameters

Table II lists the substrates material stack, their heights and electrical properties.

Fig. 3 shows the geometrical parameters of the conductors and the values obtained for the design are listed in Table III.

IV. SIMULATIONS

The proposed antenna has been simulated with Agilent ADS2003 and ADS2005 Momentum. This software is a method of moment-based full wave electromagnetic simulator. The simulated return losses for each port of the structure are shown in Fig. 4. It can be seen that both ports match the design return loss specification. The coupling between ports is also shown in Fig. 4. The simulated port isolation widely matches the design specification as it can be observed.

A tolerance analysis would show that most of the results would match the design specification. It also would show that the most important deviations are consequence of the slot and substrate tolerances.

V. PROTOTYPE MEASUREMENTS

From the described geometry, a prototype having two patches was manufactured. A photograph of this prototype is found in Fig. 5.

VI. CONCLUSION

The design of a dual-polarization stacked patch antenna has been presented. The main features of this element are a matching level and high isolation between ports achieved in a broad band. It also has low
back radiation. These features make this element suitable to develop base station antennas.

A prototype has been manufactured and measured. The measured return losses (in the range of −24 dB) and isolation between polarizations of the same patch (in the range of 36 dB) for a 24% bandwidth base station antennas.

These elements will be used in reconfigurable antennas using advanced RF combination circuits.

REFERENCES


An Electromagnetically Coupled UWB Plate Antenna

Terence S. P. See and Zhi Ning Chen

Abstract—A broadband plate antenna operating at a frequency range of 3-12 GHz is proposed for ultrawideband (UWB) applications. The plate antenna consists of a shorting wall attached to the radiator. The radiator is excited by a parasitic L-shaped plate connected to a feeding probe. The vertical section of the L-shaped feeding plate is separated at a distance from the shorting wall. With the electromagnetic coupling between the feeding plate and the radiator, a broad impedance bandwidth is achieved. Also, the antenna with reduced size is able to achieve the stable radiation performance with gain greater than 4 dBi across the entire UWB band.

Index Terms—Broadband antennas, electromagnetic coupling, ultrawideband (UWB) antennas.

I. INTRODUCTION

Suspended plate antennas (SPAs) as a variation of patch antennas feature low-profile configurations, large impedance bandwidths, and low cost [1]. The radiating plate is about half-wavelength long at the lower edge of the operating frequency range. Usually, the impedance bandwidth of SPAs can reach up to 20%-40%.

A shorting wall can be placed at the center of the radiator to halve the length of a plate radiator where the electric field of the resonant mode is zero [2]. The bandwidth of the shorted radiator on a foam substrate is larger than that of a conventional suspended plate antenna [3]. However, it is also noted that the gain of the shorted plate antenna is about half of that of a conventional suspended plate antenna due to the halved radiator [3].

In ultrawideband (UWB) applications, it is desirable for the impedance bandwidth to be at least 50% in order to cover the lower UWB band of 3.1-5 GHz or the upper band of 6-10.6 GHz or 100% for the entire UWB band of 3.1-10.6 GHz. Also, in order to prevent pulse distortions, the gain at certain directions of interest across the operating bandwidth should be consistent.

There are several ways to further enhance the bandwidth of the plate antenna, such as the addition of parasitic patches, either in stacked [4] or coplanar geometry [5], [6]. The stacked geometry has the disadvantage of increasing the thickness while the coplanar geometry increases the lateral size of the antenna. Another way to increase the impedance bandwidth is the use of L-probe feed, which introduces some capacitance to offset the feed inductance [7], [8]. The L-probe feed is able to achieve a bandwidth of about 35% [9]. The use of the shorting wall together with the L-probe feed is able to achieve a bandwidth of 40% [3].

In this communication, a broadband suspended plate antenna with a shorted wall operating from 3-12 GHz is proposed. A modified feeding probe is proposed to enhance the electromagnetic coupling between the radiator and the feeding plate for broadband impedance matching. Also, the antenna can achieve stable radiation performance with gain of > 4 dBi across the operating bandwidth.

II. ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed plate antenna and the Cartesian coordinate system. The dimensions of the antenna are given...