MINIATURE CURRENT DISCONTINUITY DEVICE ANTENNAS

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Summary  
Flush and semi-flush, Current Discontinuity antennas have been developed for VHF and UHF frequencies that exhibit good efficiency and minimum structural disturbance.

Typical antennas are .02 wavelengths high, 1/8th inch at “L” band.

An airborne, electronically steerable array for VHF, satellite applications is described.

Introduction  
The current discontinuity device in its simplest form consists of small, series connected, formed coupling loops which lie parallel to a transmission line element with the coupled loops resonated by a capacitor. The device acts to impede the current flow in the centered conductor and its operation is enhanced by resonating the coupling elements at the desired frequency, thus provide a rejection “trap”. Basic uses of this configuration are as a wave trap on an antenna structure and as a band-reject filter in a coaxial configuration. In both of the preceding applications it can be seen that the approach allows the center conductor to remain structurally undisturbed and experimental tests have shown that the physical arrangement illustrated in Figure 1 is sufficient to efficiently and effectively “couple” to the transmission line.

Under circumstances where the center conductor is of such a size that the total length of coupling elements required to surround the conductor might begin to exceed self-resonance, the paralleled inductance counter-wound configuration of Figure 2 may be utilized. This arrangement also allows the two terminals to be physically separated which is an attribute for high power applications. Figure 2 illustrates that the current discontinuity device is capable of being used around a structure of significant size. For structures greater than a portion of a wavelength; antennas must be constructed, as illustrated in Figures 3 and 4, where by paralleling many elements, a structure with a circumference greater than a wavelength can be properly excited. In this case, as well as

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1 The VHF antenna development w supported by the FAA under contract FA-67WA1632.

2 C-DD, used as abbreviation, US Patent 3, 365, 721, and Foreign Patents or Pending.
for the small structures, the device becomes a means for exciting the aircraft skin. A most important application for telemetry antennas is shown in Figure 3, wherein it has been found that a figure of revolution is not essential and thus a linear section, $\lambda/2$, of a missile or aircraft can be excited by a small flat coil, C-DD, without structurally or electrically removing a section of the airframe.

The C-DD operation is most easily described as that of a PF transformer coupling from a multi-turn primary to the elemental half-turn secondary - in this case the missile or aircraft skin. This electrical perturbation of the aircraft skin’s impedance when compounded by many closely spaced in-phase coupling elements results in a region of the surface being highly excited by the series-fed primary coil. The coil in this case takes the form of short (.09$\lambda$) lengths of “strip-circuit” transmission lines laying side by side against the insulated skin. Each coupling element loops up and returns to the next element, etc. As the total number of “turns” approaches self resonance for the highest design frequency, this particular group of turns terminate and a new group initiates. In this way the groups are all connected in parallel and at resonance all elements are essentially in phase. As a receiving structure the assembly of elements couple to currents flowing in the aircraft skin and in transmitting the elements excite currents in the skin which then radiates - with patterns nearly identical to those which would be generated by a slot-cavity structure mounted at the same location.

**Specific Adaptations For Telemetry**  This development has resulted in a low-depth class of flush and semi-flush antenna with pattern and polarization similar to that of a typical slot antenna. Thus, the radiation patterns can be predicted and calculated for cylindrical vehicles in the same manner as a slot. Since the miniature C-DD requires no “back-up” cavity the internal penetration depth is drastically reduced and structural problems may be significantly reduced. For applications where a slight protrusion or fairing can be permitted a C-DD antenna could be streamlined and built of high temperature materials so that it could be attached to the skin of a missile requiring only a feed connector cutout. The height of the fairing would be less than 0.125" high for “S” band applications. An antenna of this type was used in the following evaluation. The element used was tuned for 1100 mHz and was dimensioned as follows:

<table>
<thead>
<tr>
<th>1100 mHz Model</th>
<th>“S” Band Equivalent 2200 mHz - 2300 mHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>5.5 inches</td>
</tr>
<tr>
<td>Width</td>
<td>0.625 inches</td>
</tr>
<tr>
<td>Height</td>
<td>0.125 inches</td>
</tr>
</tbody>
</table>

Wavelength at 1100 mHz $\lambda = 10.73$ inches
Length of the antenna = 0.512 $\lambda$
Width = .058 $\lambda$
Height = .0116 $\lambda$

The cylinder for $ka = 7$ at 1100 mHz is a 2X scale model mockup to determine the patterns for a 12 inch cylinder at 2200 mHz.

Figure 5 is a vertically polarized radiation pattern of a C-DD antenna mounted transverse to the longitudinal axis of the cylinder. The $\Phi$ pattern is around the cylinder and the $\theta$ pattern is in the plane of the E vector. This particular pattern indicates that four antennas properly phased at 90° intervals would give an acceptable radiation intensity around the cylinder. The C-DD antenna measures 1.5 dB over a tuned stub mounted on the same cylinder as shown in Figure 6. The pattern of Figure 5 will broaden considerably for a structure of much greater length. The cylinder used in this case was 19.5" long (less than $2\lambda$) and is not considered valid for a much longer cylinder. It is to be expected that for a much longer cylinder the pattern would become broader. The magnitude or ratio of minima to maxima would decrease and the fore and aft nulls would start to fill in.

**Specific Systems** The following photographs Figure 7 and 8 and the dimensional drawing Figure 9 illustrate a 2150 mHz flush antenna and its characteristics for an aircraft belly-mount application. The tuning unit is a simple stub coax capacitor and may be replaced with a varactor for low power broad band tuning applications.

The active element structure remains flexible enough to be formed easily to large radii structures and can be preformed for small radii structures. Typically a .010" to .020" teflon spacer between the element and the aircraft skin furnishes proper spacing and insulation sufficient for 1 KW peak power levels.

The 3 mHz bandwidth can be broadened by increasing the width of the structure, however, the specific design applications to date have benefited by the relatively narrow band. As a transmitting antenna this narrow band materially aids in suppression of spurious radiation and in receiving applications the adequate but limited bandwidth reduces RFI products from adjacent channel interference.

Array structures, using a system of axial and peripheral elements on a cylinder, have been built at “L” band to achieve circular polarization and increased gain. This array concept has been adapted for VHF frequencies as described in the following section.

**A VHF 9 Element C-DD Airborne Array** Applications of the C-DD antenna at lower frequencies results in some attractive semi-flush designs that are small enough to be
wrapped around fuselages, wings or tails. The specific 118 to 150 mHz antenna array installation for the FAA was made as shown in Figures 10 and 11. The attachment was made without any structural cutouts, modification or reinforcement to the aircraft other than small screw fasteners and coax bulkhead connectors.

The system provides electronic remote control switching of the frequency and circularly polarized beams to 5 pre-selected segments of the upper hemisphere. Two orthogonal plane polarized, option modes were included for sampling the polarization from the ATS satellite.

The four quadrant selectable beams and the overhead mode had peak gains of over 6 DB_{iso/cP} and VSWR’s under 1.65:1. Nine elements were necessary since shadowing required that some elements could only be utilized for Port or St’bd patterns.

The January, 1968 flight tests resulted in Q5x5 signals from the satellite. Limited satellite availability has restricted the number of tests. The system installation has now been flown over 500 hours.

**Resume of C-DD Properties**  
The Current Discontinuity Device in its torroidal, wrap-around design has proven useful for exciting structures without introducing structural modifications and generally can be considered as a satisfactory, uni-frequency insulator replacement. For lightning and spurious frequencies such an installation bypasses 20 to 100 DB of the off-frequency energy spectrum. Basically, the device acts as a current equivalent of the parallel-resonant “wave-trap”.

The flat configuration where many coupling elements are fed in a desired phase relationship creates an entirely new concept for the antenna designer to adapt to structures that could not be altered sufficiently to permit installation of larger cavity or protruding antennas.
FIGURE 3
FLAT PLATE C/D ANTENNA

FIGURE 4
LARGE DIAMETER ANTENNA
ka > 1
FIGURE 6 STUB - C-DD COMPARATIVE PATTERNS

FIGURE 5 E-H PATTERNS ON A CYLINDER
FIGURE 7  BACKVIEW
C-DD FLUSH MOUNT ANTENNA

FIGURE 8  FRONT VIEW
C-DD ANTENNA
FIGURE 9 DIMENSIONAL DETAIL

FIGURE 10 VHF ANTENNA INSTALLATION
VHF AIRBORNE TRANSMIT/RECEIVE, EXPERIMENTAL,
ANTENNA ARRAY FOR SATELLITE COMMUNICATIONS RESEARCH

A new VHF semi-flush antenna design has been developed which attached to
the skin of the C-135 aircraft without requiring structural modifications other
than attachment bolts and coaxial feed-thru connectors.

The design uses 9 elements in the array. The beam is electronically steerable
and has polarization selective options.

Three elements of this array are all that would be needed with optimum
placement and orientation for practical applications aboard airliners where minimum
switching and drag is most important.

Each antenna is tunable and reaches a peak efficiency at 149 MHz of ~87% 
(dropping to ~63% efficiency at 118 MHz) with a VSWR under 1.5:1 for channel band
widths of ±.5 MHz. Broadband versions are under development, however, the tuned
system presently used provides great rejection of adjacent channel and "image"
interference and in the receive mode is easily tuned electronically with varactors.

* Kaman Nuclear US and Foreign Patents Applied For.

FIGURE 11  C-135 INSTALLATION PHOTOGRAPH