Bandwidth Enhancement and Size Reduction for Conformal Antenna by Coupling with Platform

[#]Johnson J. H. Wang and D. J. Triplett
Wang Electro-Opto Corporation
2140 Newmarket Parkway, Suite 110, Marietta, Georgia 30067, USA
email: jjhwang@weo.com

1. Gain Bandwidth Limitation of Antenna Due to Physical Size

It is well known that a fundamental gain bandwidth limitation exists for an antenna of a given electrical size, which is generally referred to as the Chu limitation [1]. As a consequence and corollary, an antenna must be sufficiently large in terms of the operating wavelength in order to be efficient. For obvious practical reasons, bandwidth enhancement and size reduction are both highly desirable for antennas, and are two facets of the same fundamental issue. Since the advent of the Chu theory six decades ago, this has been a prominent subject in antenna design. Although an enormous amount of research has been conducted, success has been marginal.

However, there are major shortcomings and ambiguities in the Chu theory when applied to real-world problems, as pointed out recently by the senior author [2, 3]. One problem is that, when mounted on a platform, the size of the antenna becomes ambiguous. This observation has led to a technique which extends the bandwidth of antennas beyond the apparent Chu limitation, and simultaneously resolves the practical problem of conformal mounting of antenna on platform. In ISAP2007, the senior author addressed the general design issues for conformal broadband multifunction antennas when mounted on an automobile [4]. Although exploiting the mounting platform to enhance antenna bandwidth is not new, the magnitude of the bandwidth enhancement in the present approach is much larger.

2. Enhancing Bandwidth and/or Reducing Size by Coupling Antenna with Platform

Recently, a need arises for an antenna that can be conformally mounted on a highly curved platform, such as the instrument pod of an aircraft, and exhibit multioctave bandwidth. To meet this need, a new approach, called “Small conformable broadband traveling-wave antennas on platform,” was conceived [5], and experimental models were successfully developed [6, 7]. However, since the platform in these models was not much larger than the antenna per se, the resulting bandwidth enhancement was limited. This paper shows that much larger bandwidth enhancement and size reduction can be achieved when the platform is much larger than the antenna. Perhaps more important is that the bandwidth is extended beyond the Chu limitation for the apparent antenna size, when a TW antenna is strongly coupled to its mounting platform.

3. Launching Appropriate Traveling Wave on Platform

The launch of an appropriate traveling wave (TW) from the TW antenna onto the platform is essential to the broadening of bandwidth, and/or reduction of antenna size, since the antenna bandwidth pertains not only to impedance matching, but also to efficiency and radiation pattern. That is, in addition to strong coupling by impedance matching techniques, launching TW of an appropriate type is also important. Discussions on general TW for antennas can be found in Walter [8]. For broadband TW on conformal antennas, those described by Goubau [9] and Attwood [10] are desirable since they are relatively independent of the frequency used. Recent discussions can be found in [11, 12].

4. Conformal TW Antenna Strongly or Weakly Coupled to Planar Platform

Figure 1 shows a photograph for a conformal TW antenna mounted on a planar conducting plate. As can be seen, the antenna consists of two parts: (1) conformal TW antenna (in the center), and (2) conducting planar platform.

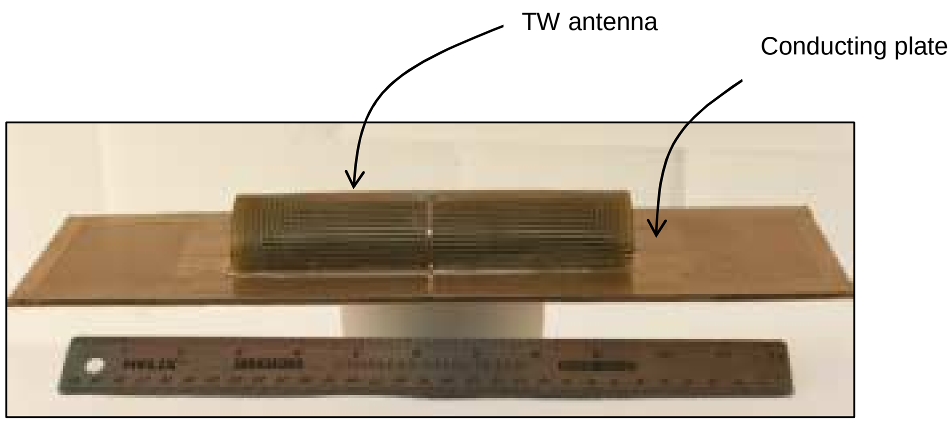

Figure 1. TW antenna on conducting platform.

The TW antenna measures 6.68-in long, 2.1-in wide, and 0.95-in high. The conducting plate measures 13.8-in by 4.5-in in area, about twice large as the antenna base. The TW antenna can be strongly, or weakly, coupled to the conducting platform so that the effective radiator includes both the TW antenna and the platform. Figure 2 shows a comparison of the SWR, over 0.04 – 7.0 GHz, between strongly coupled and weakly coupled states.

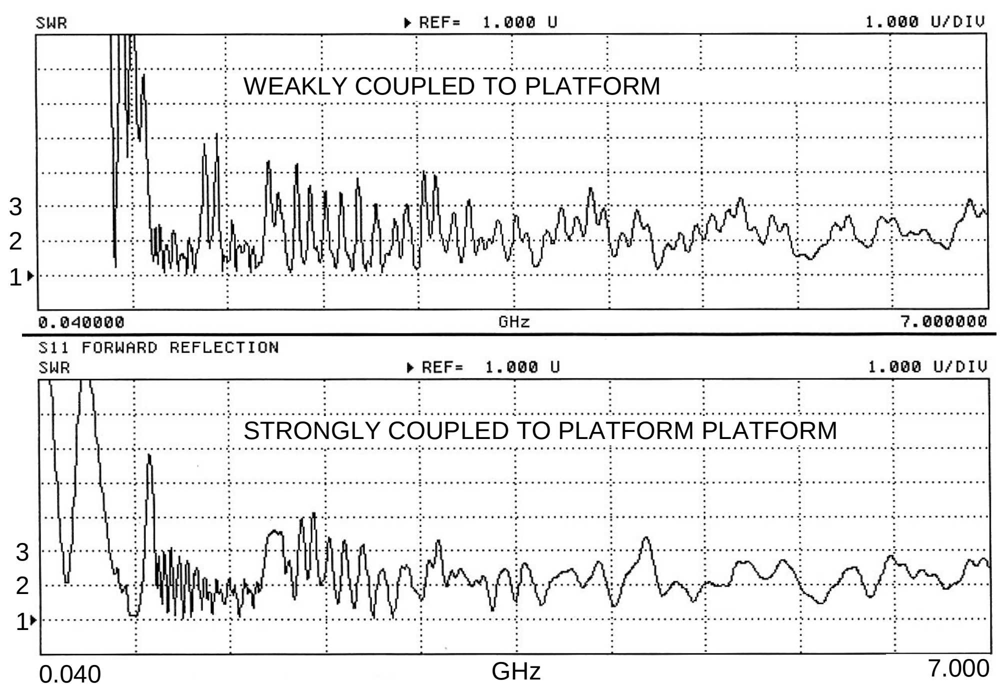

Figure 2. Comparison of measured SWR of TW antenna in Figure 1: TW antenna weakly coupled or strongly coupled to platform (upper and lower chart, respectively).

As can be seen, over 0.18-1.67 GHz, the SWR of the strongly coupled case is greatly improved from that of the weakly coupled case. In particular, SWR for the weakly coupled case is very poor at frequencies below 520 MHz; while the SWR of the strongly coupled case is fair except for the two peaks at 370 MHz and 830 MHz. It is also worth noting that for frequencies above 1.67 GHz, the SWR is fair, averaging 2:1, in both strongly and weakly coupled cases.

Figures 3 and 4 show, for the strongly coupled case, typical measured elevation patterns at azimuth angles $\varphi = 0°$ and $\varphi = 90°$, respectively, over 200 – 2000 MHz. They basically display monopole-type radiation patterns. The azimuth patterns are generally omnidirectional, but with more and more lobes emerging as the frequency increases.

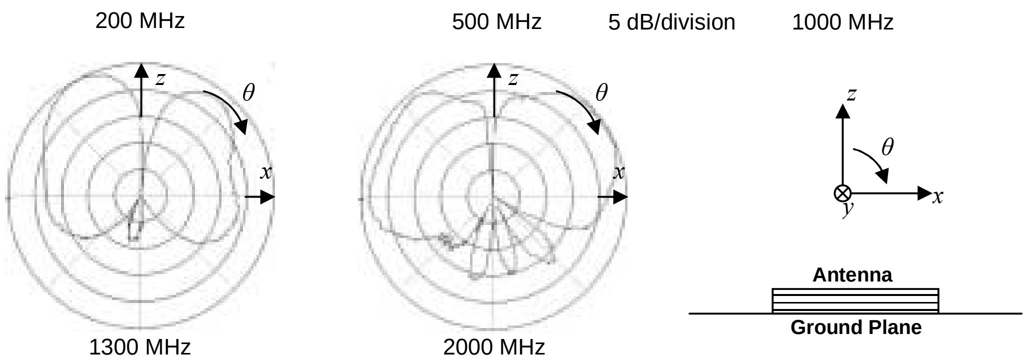

Figure 3. Typical measured elevation radiation patterns at $\varphi = 0°$ over 200 – 2000 MHz.

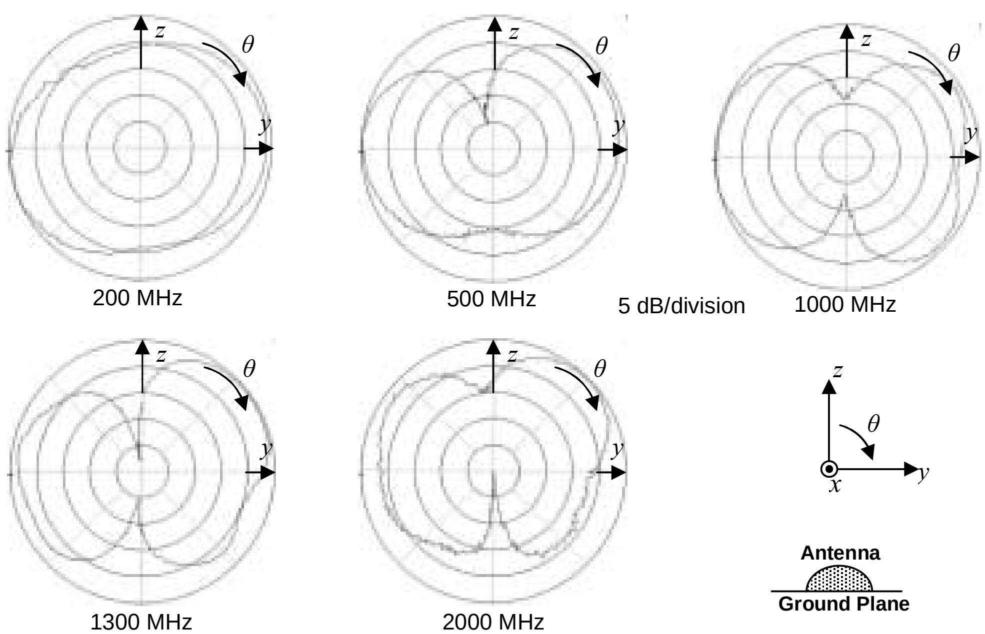

Figure 4. Typical measured elevation radiation patterns at $\varphi = 90°$ over 200 – 2000 MHz.

Not shown here are the cases in which the platform is much larger than, and strongly coupled to, the "antenna." The large platform enables the TW antenna to broaden its impedance bandwidth, and further extend it to lower frequencies. Indeed, the technique enables the reduction of "antenna size" to 1/10 or less if its mounting platform is large enough and can accommodate a structure supporting the desired TW.

5. Applications to Handheld, Personal, and Other Platforms

This technique can be applied to various handheld, personal, and other platforms on which a conformal low-profile antenna is needed, either to enhance its frequency bandwidth or to reduce its apparent "antenna size." As discussed in Section 3, the TW on the platform can be of a very simple type, which can be supported by a surface structure such as a conducting strip over the surface of the platform, which can be either conducting or nonconducting. Note that a nonconducting surface can often be made conducting by using modern techniques that can "print" circuits on a variety of materials.

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