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DESIGN OF A FRONT-END ANTENNA MODULE FOR WIDEBAND UNIVERSAL COMMUNICATION RECEIVER

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1 Introduction

In a Universal Communication Receiver or UCR, the frequency coverage is very wide ranging from 2MHz to 2GHz. Hence a single RF front-end will not be able to cover such a wide bandwidth, and it is necessary to implement separate RF front-ends (including antennas) to cope with different frequency bands[1].

In this paper, a design of a front-end antenna module for 900MHz band is presented. The concept is to make an antenna module which includes the front-end filter and RF preamplifier. This RF module is enclosed in a metal box on which the antenna is located (see Fig.1). Instead of the traditional monopole antenna, a modified inverted-F type has been used for overcoming the mechanical drawbacks of an external antenna such as vulnerable to damage. Because the antenna height is low, it is expected that its input impedance will be small. However, with the antenna and the RF circuit designed as a single module, the problem of impedance matching becomes less severe.

Several methods of broadening the antenna bandwidth have been proposed in this paper. It has been observed that a conducting plate attached to the antenna module has a very large effect on the bandwidth. Further simulation results show that whether this effect is beneficial will depend on the mounting position and the size of this plate.

2 Current Distribution and Patterns

A complete antenna module is shown in Fig.1. The RF circuit is enclosed in a $20 \times 30 \times 50$(mm) rectangular conducting box. The antenna mounted on the box is an inverted-F type[2] combined with a rectangular loop. The main features of this antenna module are low profile, polarization diversity (three-dimensional), frequency tunable by a loaded capacitor and broad bandwidth.

This antenna module has been analyzed using the Numerical Electromagnetics Code (NEC-2)[3] which embodies the method of moments. A wire grid model of this antenna module is shown in Fig.2. The radius of the wires used in the wire grid is 0.51mm. In Fig.2, the arrows on the wires represent the current amplitude and direction.

It is interesting to note that the currents flow in the same direction for parallel wires which may reinforce the radiation of the currents in that direction. The current distribution has a maximum near the feed point and a minimum at the far end of the loop (looking from the feed point). Since the antenna height is very low (10mm), the horizontal component of its electric field can not be expected to be very high because of the cancelling effect of the box. This can be seen from the fact that all currents on the horizontal wires of the box flow in opposite directions to their corresponding antenna elements. It has been observed that the current distribution at the bottom of the box is relatively small but not zero. This suggests that the performance of the antenna module will be affected by any additional circuit board attached to it. As to be shown in section 4, this effect is largely depending on how the circuit board is attached.

Fig.3 shows the three-dimensional radiation patterns for the vertical and horizontal components. The vertical pattern is similar to that of a dipole with a power gain of 1.5dBi. It can be seen from the horizontal pattern that even though the antenna module has a smaller gain (-4.9dB) in horizontal direction than in the vertical direction, its radiation pattern is almost omnidirectional except for big degradations at $\phi = 20°, 200°$ and $\theta = 90°$. This result suggests that the antenna module will work well in a personal communication environment where antennas are required to have cross-polarized response. If a higher horizontal gain is desired, the antenna structure should be modified to eliminate the cancelling effect of the conducting box to the horizontal component[4].

3 Bandwidth

Usually a small antenna has a very narrow bandwidth. For an inverted-F type antenna, its bandwidth is mainly determined by its height[5]. Previous studies have been carried out on how to increase the bandwidth of an inverted-F type antenna such as mounting it on a conducting box[6] or adding parasitic element[7]. But as the antenna module is very small, neither of these methods will be practical. Hence in this paper, the following methods have been used.

As mentioned in section 1, because the antenna and the RF circuit is to be designed as a whole module, an added flexibility is to choose the impedance of the RF circuit to optimize the antenna bandwidth. As observed in Table 1, the maximum bandwidth occurs not with $R_0 = 50\Omega$ but with $R_0 = 20 \sim 35\Omega$ for the antenna shown in Fig.1. Here R_0 denotes the RF circuit impedance at the terminal connected to the antenna.

Table 1: Bandwidth vs different matching resistance

$R_0(\Omega)$	5	10	15	20	25	30	35	40	50
f_0(MHz)	1010	1010	1010	1005	1000	1000	995	990	980
BW(%)	2.2	4.3	5.2	5.8	5.8	5.8	5.8	5.3	4.8

Another method of increasing the antenna bandwidth is to introduce a series capacitor C on the wire segment between the two vertical elements of the inverted-F antenna. The VSWR for different values of C is shown in Fig.4. The important point to note is that the antenna resonant frequency varies with C. This suggests that different C values can be used for different radio channels. Hence, by tuning the capacitor from 1pF to 3pF, the bandwidth coverage will increase from 5% to over 10% which may be sufficient for personal communication systems.

4 Effect of an External Circuit Board

An important factor influencing the performance of this antenna module is the effect of adjacent objects. In this paper, only analysis of the effect of a circuit board attached at the bottom of the module is discussed. To model this board, we replace it with a metal plate which is modelled as wire grids (as shown in Fig.5).

Table 2: Bandwidth vs conducting plate length

L(mm)	40	50	60	70	80	90	100	110	120
f_0(MHz)	950	950	950	1050	1050	1040	1030	1020	1020
BW(%)	13	20	20	26	27	18	10	9	8

Calculations have been performed for different board sizes and mounting positions. Table 2 shows that the bandwidth is closely related to the board size. A maximum bandwidth is achieved with $L \approx 80$mm.

If the board is attached to or separated from the bottom of the module, a large increase of the bandwidth is observed. However, if the board is connected to the module by a wire at the corner of the board, the bandwidth then decreases. This can be interpreted by the changes of current distribution. As long as the board is mounted so as not to cause any perturbation to the current distribution, the effect of the circuit board will be beneficial to the bandwidth. If the board is connected at a corner of the module, the current distribution will be changed resulting a degradation of the bandwidth.

5 Conclusion

In this paper, the design of a front-end antenna module for UCR and its performance analyses by computer simulations have been presented. Some proposals have been made in order to increase the antenna bandwidth which tends to be a critical problem for small antennas. An external circuit board gives a very large effect on the bandwidth. The analyzed results have shown that it is better to attach the board in such a way that it does not give obvious perturbation to the current distribution on the module.

The idea of implementing the antenna and RF circuit as a single module has an advantage of standardizing the front-end module. In this case, the front-end antenna module can also be used for other applications such as personal communication terminals thereby reducing the development cost of such terminals.

Acknowledgement

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References

[1] K.S.Chung, *et al.*, *A Study of Front End and Antenna Integration for a Wideband Receiver*, Research Report for DSTO of Australia under contract No.202346, 1991

[2] K. Fujimoto, *et al.*, *Small Antennas*, Research Studies Press, 1987

[3] G.J.Burke and A.J.Poggio, *Numerical Electromagnetics Code (NEC)—Method of Moments*, Lawrence Livermore National Laboratory, January 1981

[4] R.B.Seale and K.S.Chung, "Modified Transmission Line Antenna on a Conducting Box," *Proc. of Interna. Sym. on Ant. and Propaga.*, 1992

[5] T.Taga and K.Tsunekawa, "Performance analysis of a built-in planar inverted-F antenna for 800 MHz band portable radio units," *IEEE Journal on Selected Areas in Communications.* Vol.SAC-5, No.5, pp.921-929, June 1987

[6] K.Sato, *et al.*, "Characteristics of planar inverted-F antennas on a rectangular conducting body," *Transactions of IEICE*, Japan, J71-B, pp.1237-1243, 1988 (in Japanese)

[7] J.Rasinger, *et al.*, "A new enhanced-bandwidth internal antenna for portable communication systems," *Proc. of 40th IEEE Vehicular Tech. Conference.*, pp.7-12, 1990

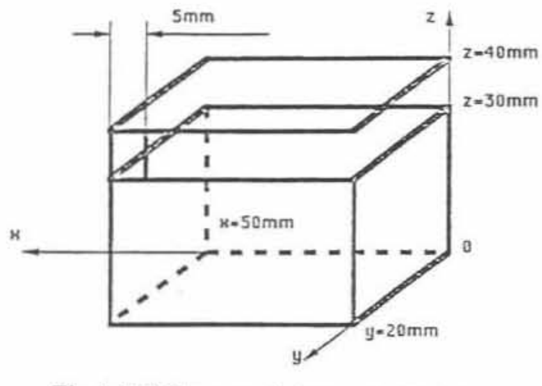

Fig.1 RF Front-end Antenna Module

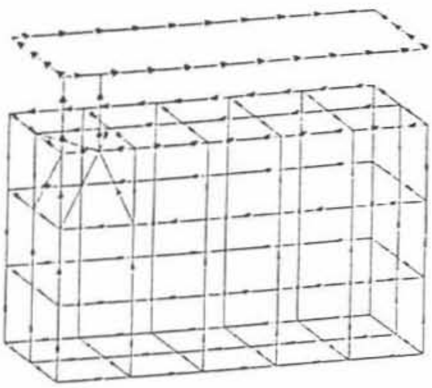

Fig.2 Wire-grid Model of the Module with
Current Distribution

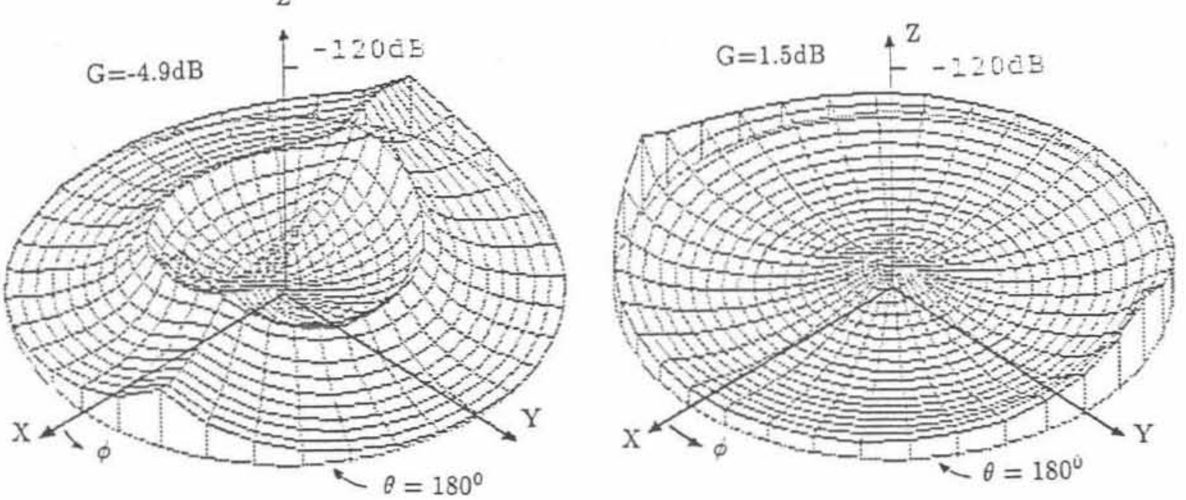

Fig.3 Three-dimensional Radiation Patterns of the Module

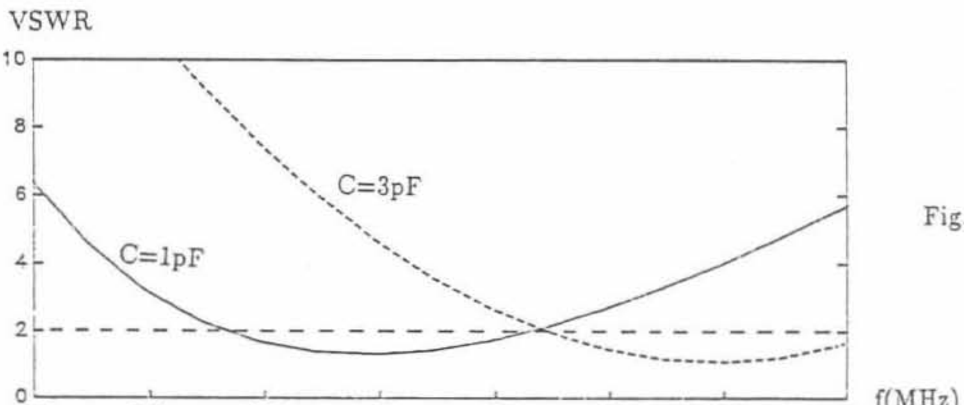

Fig.4 VSWR for
Different C Values

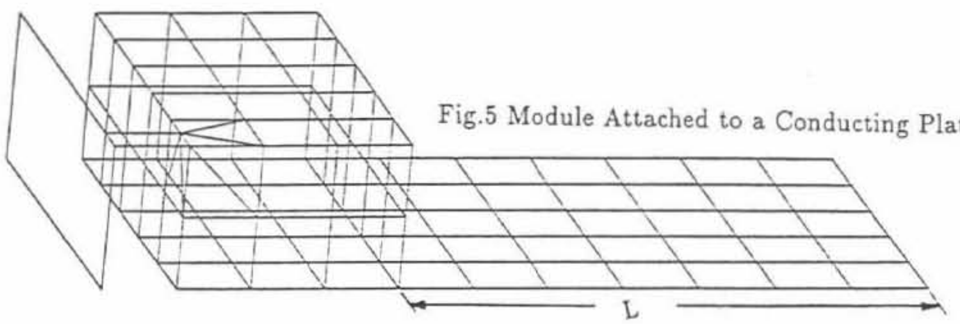

Fig.5 Module Attached to a Conducting Plate