The Design on a Wideband Active Printed Dipole Antenna using a Balanced Amplifier

Sung-Ho Lee[1] · Se-Woong Kwon[1] · Byoung-Moo Lee[1] · Young-Joong Yoon[1] · Woo-Young Song[2]

Abstract

In this paper, the active integrated antenna(AIA) using a wideband printed dipole antenna and a balanced amplifier is designed and fabricated. The proposed active printed dipole antenna has characteristics of easy matching, wide bandwidth and higher output power. To feed balanced signal to printed dipole, a Wilkinson power divider and delay lines are used. The measured result shows that, at 6 GHz center frequency, the impedance bandwidth is 22 % (VSWR < 2), 3 dB gain bandwidth is 28 %, the maximum gain is 14.77 dBi, and output power at P1 dB point is 23 dBm.

Key words : Wideband, Printed Dipole Antenna, AIA

Ⅰ. Introduction

Recently, wireless communication systems require highly compact and lightweight transmitters with long operating life times. Since the power amplifier (PA) consumes the majority of the power in the transmitter, much attention is paid to maximizing the efficiency of this crucial component.

The technique for achieving high efficiency and minimum circuit size was demonstrated by using the active integrated antenna (AIA) concept. A active integrated antenna (AIA) has its advantages of long operation time, low noise, compactness, and high functionality. The AIA approach has been taken in the design of various circuits, such as phased array, power amplifier integrated antenna, RF/IF conversion antenna, and so on [1]~[3].

In this paper, we propose a wideband AIA. The AIA is composed of a printed dipole antenna and a balanced amplifier which can provide 3 dB higher output power than a single amplifier and easy matching using power divider and delay line.

Ⅱ. Design Principles

2-1 Wideband Printed Dipole Antenna

The designed printed dipole antenna is shown in Fig. 1. The length (2L1 + L2 + G) of antenna is designed to be about $\lambda/2$ long. To obtain a wideband characteristic, a printed dipole antenna must have the arm length with 0.9 ~ 1.1 the width to length ratio (W/L) and the gap(G) of 0.1L[4].

The designed antenna is fed by a microstrip coupled line of 180° phase difference using Wilkinson power divider and two 90° delay lines, which are located in front and in the rear of the amplifier. Since a dipole antenna cannot radiate even-mode signal, it is an open load on microstrip coupled line for even-mode. Accordingly, unwanted modes can be suppressed by a dipole antenna[5].

The printed dipole antenna is simulated by CST Microwave Studio, and the design parameters are shown in Table 1.

Table. 1. Design parameters.

Parameter	Length (mm)
W	9
L1	10.73
L2	2
G	2

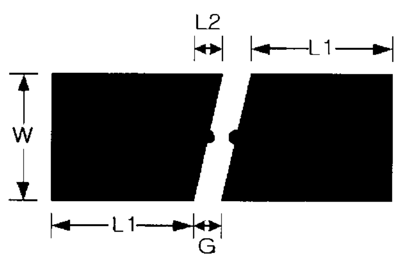

Fig. 1. Designed printed dipole antenna.

2-2 Balanced Amplifier

A 3-dB Wilkinson power divider is used in front of amplifiers so that input signal divides evenly into the two ports.

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If the characteristic impedance of each port of a Wilkinson power divider is 50 Ω, a Wilkinson power divider can be matched by two $\lambda g/4$ transmission lines of 70.7 Ω and a 100 Ω resistor. S-parameters of a Wilkinson power divider are given by

$$S_{11} = S_{22} = S_{33} = S_{23} = S_{32} = 0 \tag{1}$$

$$S_{21} = S_{31} = S_{12} = S_{13} = \frac{e^{-j\pi/2}}{\sqrt{2}} \tag{2}$$

A balanced amplifier is often used for wider bandwidth, higher stability and better reliability in spite of disadvantages of high DC power consumption and relatively large size. By using 3-dB coupler at input and output of two identical amplifiers, maximal operational power level is increased twice as much as a single-ended amplifier. In addition, if one of the balanced amplifier is not operated, the other is still operated in spite of 6-dB gain loss.

The return loss and gain are given by

$$S_{11} = \frac{1}{2}(S_{11a} - S_{11b}) \tag{3}$$

$$S_{21} = \frac{1}{2}(S_{21a} + S_{21b}) \tag{4}$$

As a balanced amplifier is shown in Fig. 2, each line has 50 Ω impedance. Because the Wilkinson power divider evenly divides the input signals into each line, phase at each path (path 1 and path 2 in Fig. 1) has 180° difference, and the balun for feeding the dipole antenna feeding is not needed.

As reflected signal at each amplifier is cancelled by 90° delay line, the balanced amplifier improves the input return loss. Also, a printed dipole antenna is connected to balanced amplifier so that 3-dB power loss at the input of the balanced amplifier is compensated.

The designed balanced amplifier uses Gali-1 amplifier chip

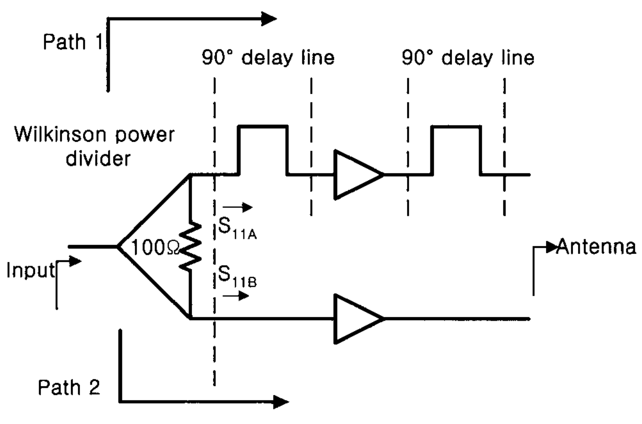


Fig. 2. Diagram of balanced amplifier.

module of Minicircuit Com., and is simulated by Agilent's ADS.

Ⅲ. Experimental Results

In this paper, a dielectric substrate which has $\varepsilon_r = 2.5$, h =1.508 mm, and t=0.034 mm is used.

Unlike conventional 50 Ω amplifier design, the output port of an AIA is free space. Therefore, the power measurement of the AIA is more difficult when compared to a conventional active circuit. For power measurement of the active printed dipole antenna, the passive printed dipole antenna without amplifiers is used. In this power measurement, the same input power is applied to both the active and passive printed dipole antennas. For exact power measurement of the active printed dipole antenna, the radiation patterns of both antennas are identical. Therefore, this must be confirmed by measuring the radiation patterns of both the active and passive printed dipole antennas.

Fig. 3 shows the measured return loss of the passive printed dipole antenna. As shown in Fig. 3, it has wide bandwidth of 22 % (5.44 GHz~6.75 GHz) at 6 GHz.

Fig. 4 is showing the measured radiation pattern at 6 GHz of center frequency. At Fig. 4, cross polarization levels are −28

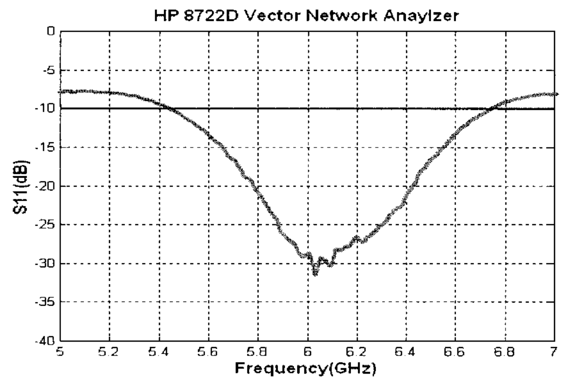
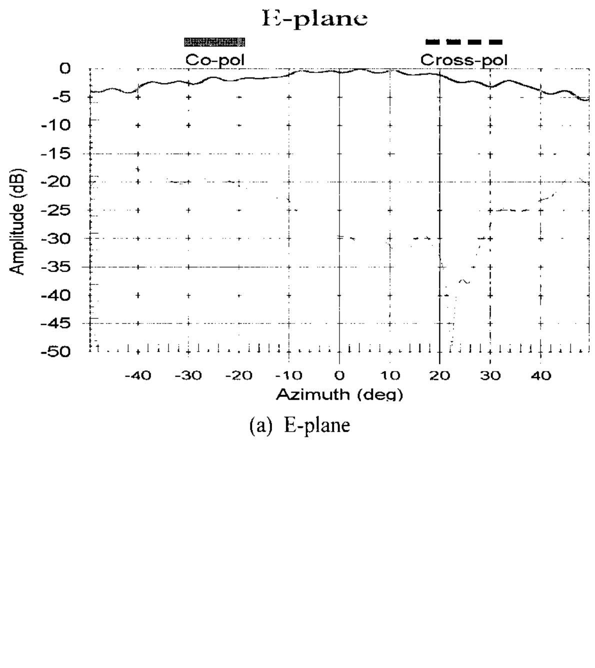
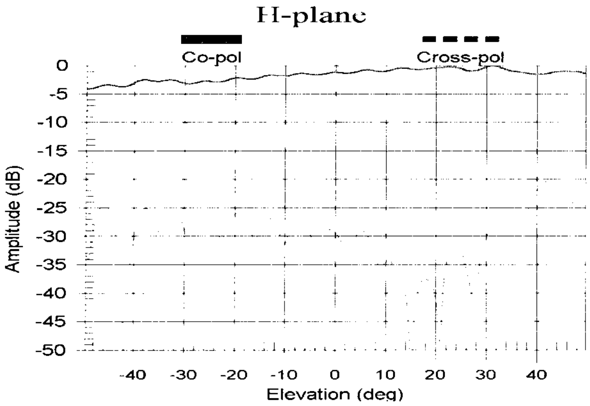


Fig. 3. Return loss of designed printed dipole antenna.



(a) E-plane

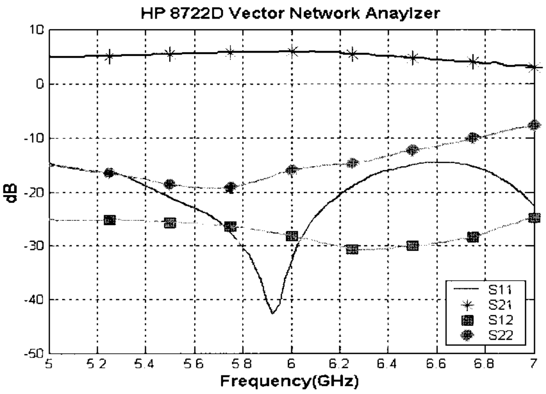


(b) H-plane

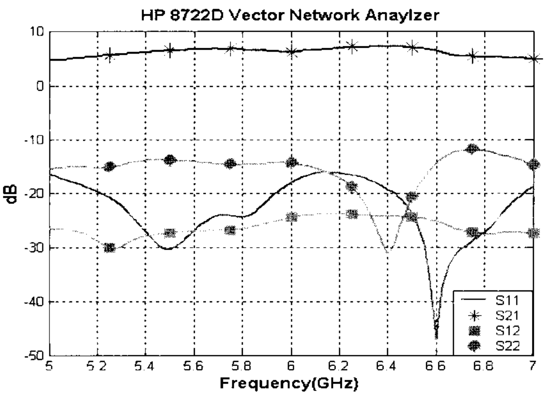
Fig. 4. Radiation pattern of designed printed antenna(6 GHz).

dB at main direction, and below −17 dB over all directions. Also, it is thought that the asymmetry of radiation pattern is due to the antenna feed circuit. The measured antenna gain is 5.23 dBi.

Fig. 5. (a) shows S-parameter of the amplifier at path 1



(a) Amplifier at path 1



(b) Amplifier at path 2

Fig. 5. S-parameter of designed balanced amplifier.

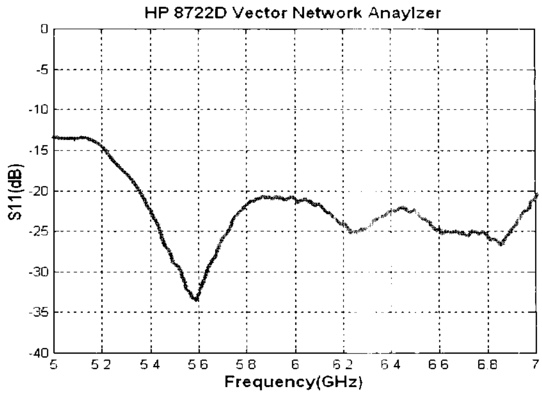
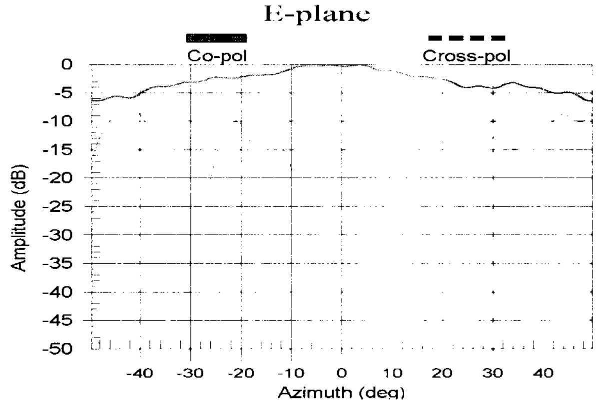
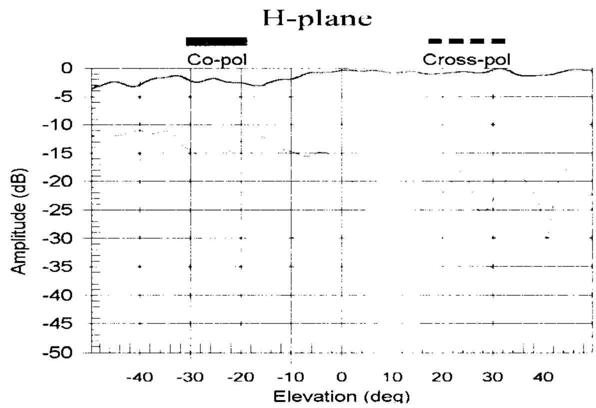


Fig. 6. Return loss of designed AIA.



(a) E-plane



(b) H-plane

Fig. 7. Radiation pattern of the active printed dipole antenna (6 GHz).

while Fig. 5. (b) is showing S-parameter of the amplifier at path 2.

At 6 GHz, the gains of amplifiers at path 1 and path 2 are 5.82 dB and 6.14 dB, respectively. The reason of difference is the different length between path 1 and path 2.

Fig. 6 shows the measured return loss for the active printed

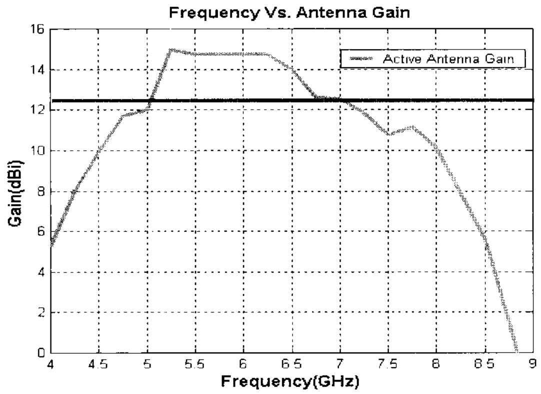


Fig. 8. Gain of the active printed dipole antenna.

dipole antenna. The return loss has the value of VSWR < 2 over all usable frequencies due to using the Wilkinson power divider and 90° delay line at input.

The radiation patterns of the active printed dipole antenna are shown in Fig. 7. The cross polarization levels are −17 dB at 6 GHz. It is slightly higher than a passive printed dipole antenna, which is maybe due to the effect of balanced amplifier that a printed dipole antenna feeder uses. As measured result, it is confirmed that the radiation pattern of the active printed dipole antennas is similar to that of the passive printed dipole antenna.

Fig. 8 shows the measured gain of the active printed dipole antenna versus frequency. Gain of the active printed dipole antenna is 14.77 dBi at 6 GHz. Since 9.54 dB higher gain is obtained compared to the passive printed dipole antenna, the gain of the balanced amplifier is 9.54 dB. Also, 3-dB gain bandwidth is 1.7 GHz (28 %) between 5.02 GHz and 6.72 GHz.

The output power of the active printed dipole antenna is measured using the measuremtent mentioned previously. The measured output power versus input power for the active printed

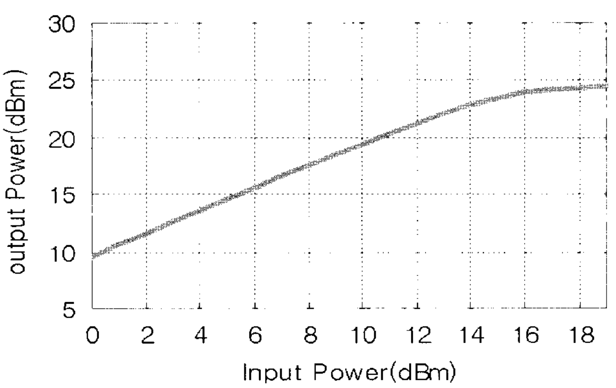
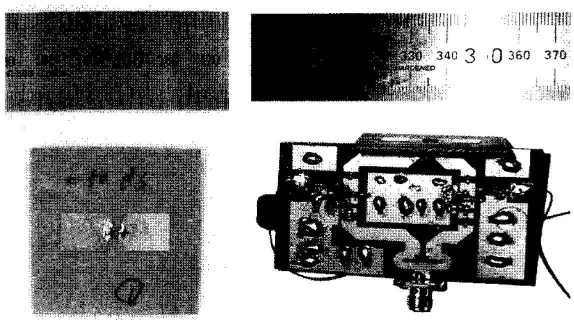


Fig. 9. Input power versus output power of the active printed dipole antenna.



(a) Printed dipole (b) AIA

Fig. 10. Fabrication of the active printed dipole antenna.

dipole antenna at 6 GHz is shown in Fig. 9. The measured maximum output power at P1dB point is 23 dBm. This output power of the active printed dipole antenna is about 3 dB higher than that of single Gali-1 amplifier which is described at manufacturer's datasheet.

The picture of fabricated antennas is shown in Fig 10.

Ⅳ. Conclusions

In this paper, the active integrated antenna (AIA) using a wideband printed dipole antenna and a balanced amplifier is designed and fabricated. In the designed AIA, the feed line uses microstrip coupled line using Wilkinson power divider and two 90° delay lines. As the 9.54 dB balanced amplifier is connected to wideband printed dipole antenna which has bandwidth of 22 % (5.44 GHz~6.75 GHz) at 6 GHz. AIA obtains 3-dB Gain bandwidth of 28 % (5.01 GHz~6.71 GHz), and shows radiation gain of 14.77 dBi at 6 GHz center frequency. By measurement using a passive printed dipole antenna as reference, 23 dBm of AIA output power at P1dB point is obtained.

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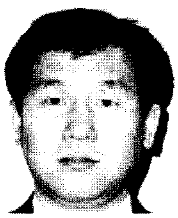

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