# Small Resinous UWB Chip Antenna using Metal Powder


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***Abstract*—In this paper, a small chip UWB antenna loaded with PPS resin mixed with metal powder was developed. The metal powder is mixed with PPS to increase the permittivity of the element. The size of the dielectric chip element is $7.4\,\mathrm{mm} \times 10.1\,\mathrm{mm} \times 0.94\,\mathrm{mm}$, on the FR-4 substrate of the size $20\,\mathrm{mm} \times 42\,\mathrm{mm} \times 0.5\,\mathrm{mm}$. The VSWR of the antenna is lower than 2.0 for 3.0–5.0GHz. The frequency characteristics of the antenna gain and group delay are very flat. An omnidirectional radiation characteristic is obtained at $-2\,\mathrm{dBi}$ for vertical polarization.**



***Index Terms*—Antenna measurement, dielectric loaded antenna, dielectric material, metal powder, monopole antenna, resin, UWB antenna**


## I. Introduction

It is known that loading an antenna with dielectric reduces the frequency response of an antenna according to the square of the dielectric constant[1]. By using this technique, small ceramic chip antennas for UWB (Ultra-Wideband) systems have obtained[2][3]. On the other hand, metal powder has been used to control the permittivity or permeability by mixing it with resin, rubber or other materiarls[4][5]. Using soft magnetic metal powder, a band pass filter for UWB communication systems were developed[6][7]. In this paper, a small chip UWB antenna was composed by using PPS (polyphenylene sulfide) resin mixed with metal powder as dielectric material. The frequency range to be mainly considered in this paper is 3–5 GHz.

## II. Resinous chip antenna structure

Fig.1 shows the structure of the developed resinous chip UWB antenna. Essentially, it is a monopole antenna miniaturized by loading the dielectric material. As shown in the Fig.1, it is composed of a resinous chip element of the size $7.4\,\mathrm{mm} \times 10.1\,\mathrm{mm} \times 0.94\,\mathrm{mm}$, on the dielectric substrate (FR-4) of the size $20\,\mathrm{mm} \times 42\,\mathrm{mm} \times 0.5\,\mathrm{mm}$. The element is fed by a microstrip line of $0.7\,\mathrm{mm} \times 30\,\mathrm{mm} \times 0.018\,\mathrm{mm}$. The size of the ground plane is $20\,\mathrm{mm} \times 26\,\mathrm{mm} \times 0.018\,\mathrm{mm}$.

We use the PPS engineering resin for a binder of the element. The PPS is known as its heat resistibility and incombustibility. It is feasible to mold PPS by injection for mass production. We fabricate the antenna by bonding in this study. The metal powder (Ni-Fe-Cr alloy) is mixed with PPS to increase the permittivity of the element. The permittivity of the resin can be controlled by changing the mixture ratio of metal powder. Table I shows the material characteristics of antenna element. The permittivity is measured using coaxial airline S-parameter method [8] at $4\,\mathrm{GHz}$. The measured frequency is The real part of relative permittivity of PPS is $3.54$. The permittivity of the PPS mixed with metal powder was increased to be $35.0$.

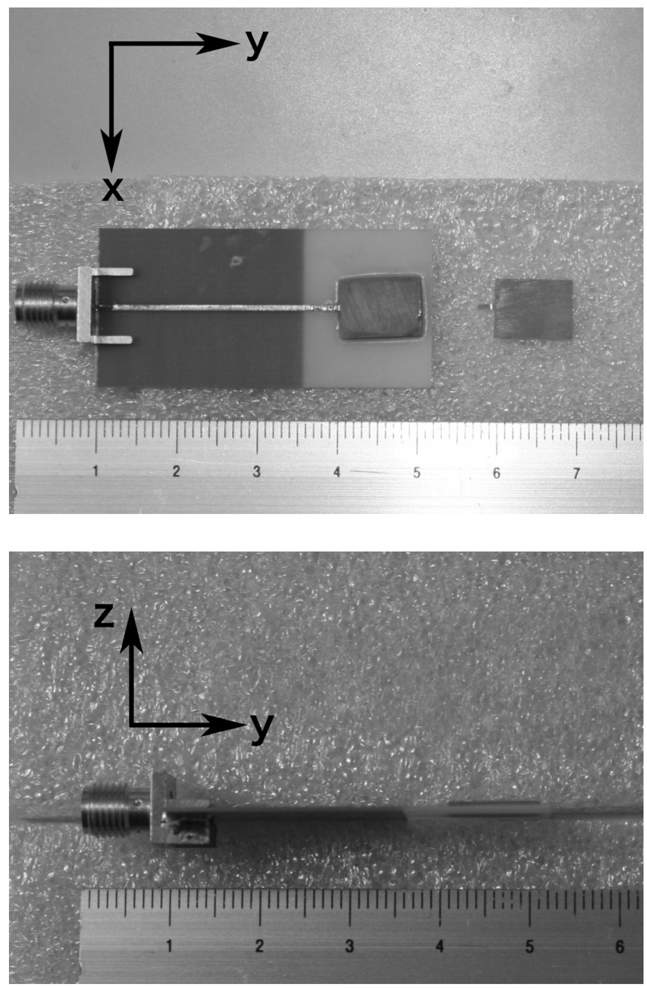


Fig. 1. The structure of the chip UWB antenna.

TABLE I
MATERIAL CHARACTERISTICS

| Filler | vol.% | $\varepsilon_r'$ | $\varepsilon_r''$ | $\tan\delta$ |
|---|---|---|---|---|
| PPS | – | 3.54 | 0.01 | 0.003 |
| Metal-powder mixed PPS | 20 | 35.0 | 0.97 | 0.033 |

## III. MEASUREMENT RESULTS

Fig.2 shows the measured VSWR of the chip UWB antenna. The dotted line shows VSWR of the PPS antenna, the solid line shows the case of the metal powder mixed PPS antenna. As shown in Fig.2, the both antennas satisfy VSWR$< 2.0$ for 3.0-5.0 GHz. It is observed that the VSWR of the metal powder mixed antenna is much lower than the VSWR of the PPS antenna for most frequencies.

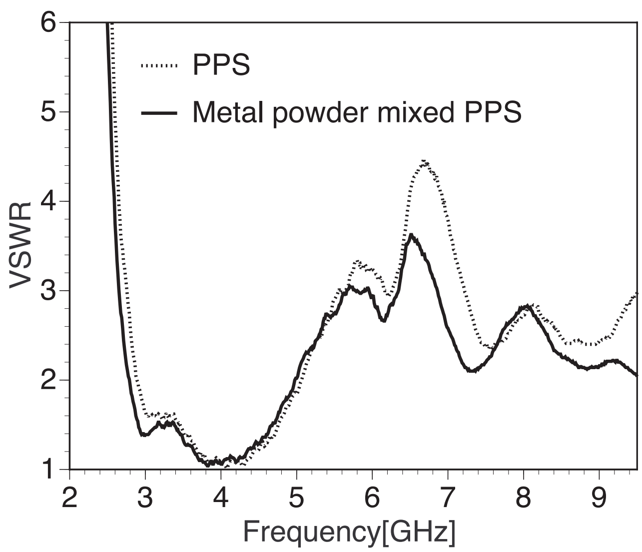


Fig. 2. VSWR of the chip antennas

To measure absolute antenna gain and group delay, we performed the complex three-antenna method [9][10]. Three broadband antennas are required to perform the three-antenna method. Thus we use the PPS chip antenna and two double ridge guide horn antennas (DRGH, smaller and larger ones). Table II shows the size of DRGH antennas.

TABLE II
SIZE OF DOUBLE RIDGE GUIDE HORN ANTENNA USED FOR THREE-ANTENNA MEASUREMENT

| DRGH | Aperture | length |
|---|---|---|
| Small | $10.0 \times 5.65\,\mathrm{cm}$ | $11.49\,\mathrm{cm}$ |
| Large | $17.5 \times 12.0\,\mathrm{cm}$ | $21.23\,\mathrm{cm}$ |

The gain of the PPS antenna is measured for $z$-axis direction and $y$ polarization. The transfer functions ($S_{21}$) for each pairs of the antennas are measured by an Agilent 8510C vector network analyzer with a S-parameter test set in an anechoic chamber. The distance between two antennas is set to 3 meter. To reduce the ripples caused by multipath, the time gating method is applied for measured results [11][12]. Fig.3 shows the measured frequency characteristics of antenna gains. The solid line shows the absolute gain of the PPS chip antenna, the dotted line shows that of larger DRGH, the dashed line shows that of smaller DRGH. The catalogue values of the larger DRGH are also shown in the Fig.3 as small circles. As show in the Fig.3, the maximum gain of the PPS chip antenna is measured as $-1\,\mathrm{dB}$ at $7\,\mathrm{GHz}$, the local minimum gain is measured as $-7.3\,\mathrm{dB}$ at $8.7\,\mathrm{GHz}$. The difference between measured and catalogue value of the larger DRGH is about $\pm 1\,\mathrm{dB}$, thus we thought that the sufficient accuracy was obtained in this measurement.

Fig.4 shows the measured frequency characteristics of relative group delays of the antennas by the complex three-antenna method. In Fig.4, three lines describe for the measured antenna group delay as same as Fig.3. To reduce ripples of the frequency characteristics, smoothing is applied to the measured data by calculating $250\,\mathrm{MHz}$ span moving average, thus the some peaks were eliminated. As shown in Fig.4, the group delay of the DRGH represents the electric length of each antenna. Fig.5 shows the measured group delay of the PPS antenna. As shown in Fig.5, the group delay is around $0.15\,\mathrm{ns}$ for almost frequencies, however drop downs are observed at $3\,\mathrm{GHz}$ and $6.5\,\mathrm{GHz}$.

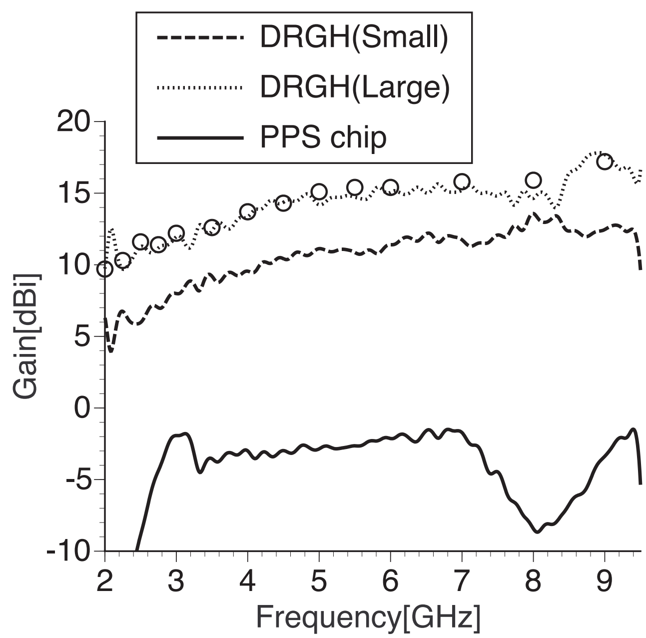


Fig. 3. Gain of the antennas measured by complex three-antenna method.

Figs.6–9 show the measured radiation gain pattern of the metal-powder mixed antenna at 3.96 GHz and $4.49\,\mathrm{GHz}$. The dashed line shows the absolute gain of $3.96\,\mathrm{GHz}$ and the solid line shows that of $4.49\,\mathrm{GHz}$. Fig.6 and Fig.7 show the H-plane ($zy$-plane) radiation pattern of the metal powder mixed PPS antenna for co-polarization ($z$-pol) and cross-polarization ($x$-pol). As shown in Fig.6, approximately omnidirectional

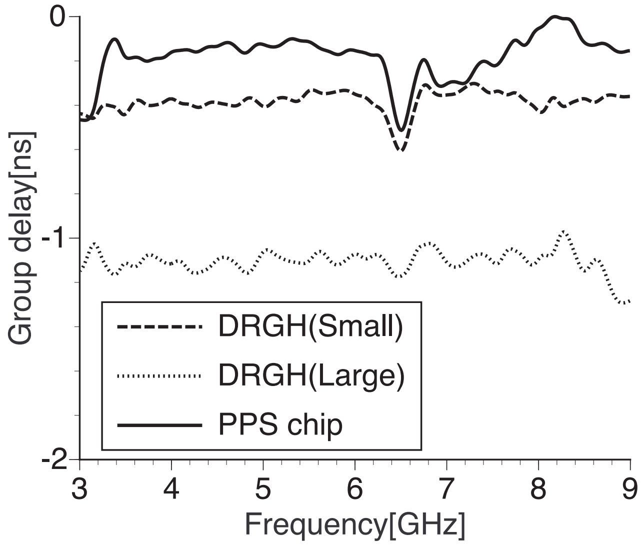


Fig. 4. Group delay of the antennas measured by complex three-antenna method.

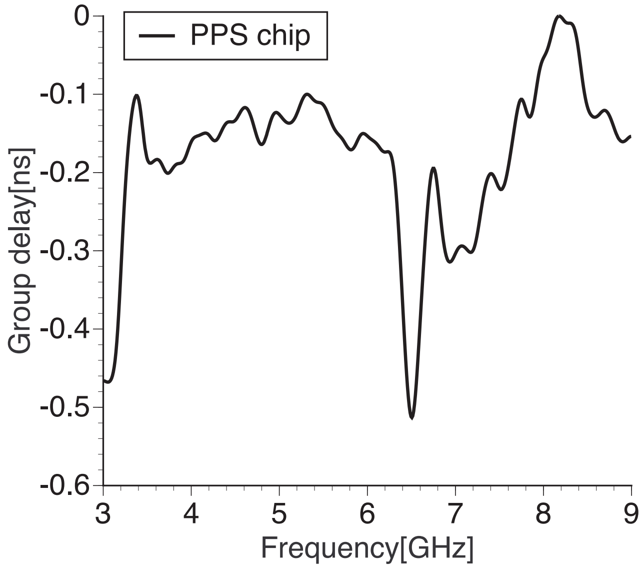


Fig. 5. Group delay of the PPS antenna measured by complex three-antenna method.

radiation pattern is obtained. The absolute radiation gain is around $-2\,\mathrm{dBi}$.

Fig. 8 and Fig.9 show the E-plane ($xy$-plane) radiation pattern of the metal powder mixed antenna for co-polarization ($x$-pol) and cross-polarization ($z$-pol). As shown in Fig.8, eight-shape radiation pattern like as dipole radiation is observed. Maximum gain $3\,\mathrm{dBi}$ is observed at $130\,\mathrm{deg.}$ and $230\,\mathrm{deg.}$ Fig.9 shows the E-plane radiation pattern for the cross-polarization. Thus, the gain is below $-4.3\,\mathrm{dBi}$.

## IV. Conclusion

In this paper, a small chip UWB antenna using PPS resin mixed with metal powder was developed. The size of the

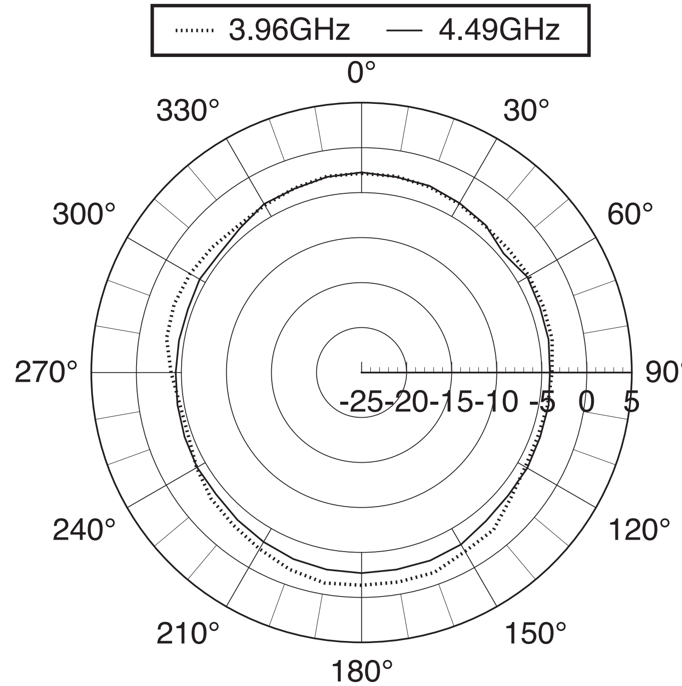


Fig. 6. H-plane co-polarization radiation pattern of the metal powder mixed antenna ($y$-pol in $zx$-plane).

dielectric chip element is $7.4\,\mathrm{mm} \times 10.1\,\mathrm{mm} \times 0.94\,\mathrm{mm}$, on the FR-4 substrate of the size $20\,\mathrm{mm} \times 42\,\mathrm{mm} \times 0.5\,\mathrm{mm}$. The VSWR of the antenna is lower than 2.0 for $3.0$–$5.0\,\mathrm{GHz}$. The frequency characteristics of the antenna gain and group delay are very flat. An omnidirectional radiation characteristic is obtained at $-4\,\mathrm{dBi}$ for vertical polarization. The transmission efficiency evaluation actual environment is left for further study.

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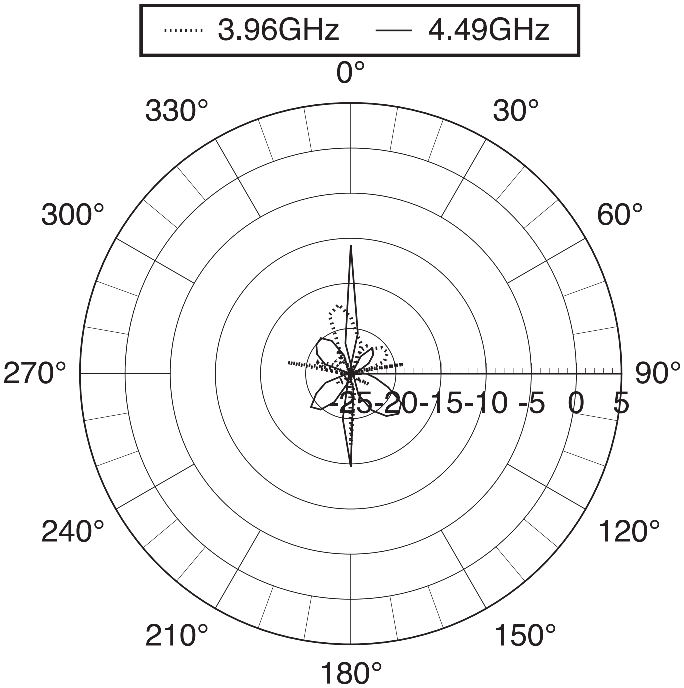


Fig. 7. H-plane cross-polarization radiation pattern of the metal powder mixed antenna ($x$-pol in $zx$-plane).

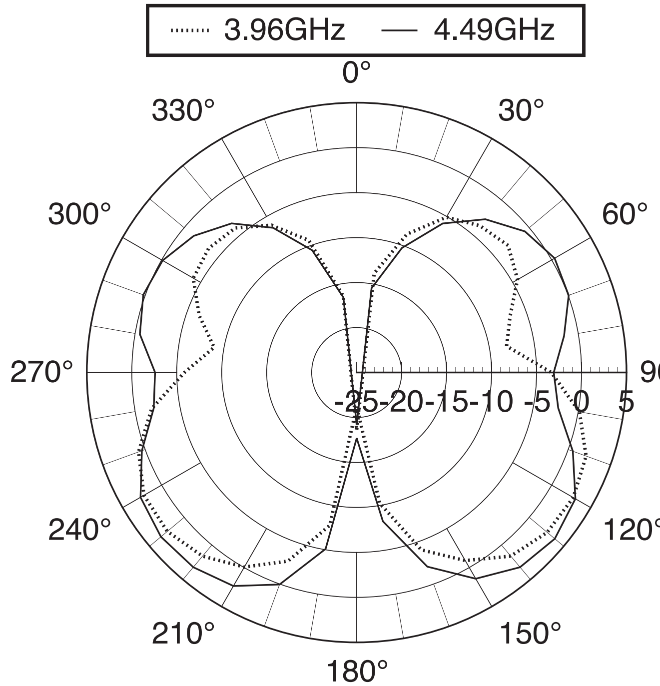


Fig. 8. E-plane co-polarization radiation pattern of the metal powder mixed antenna ($x$-pol in $xy$-plane).

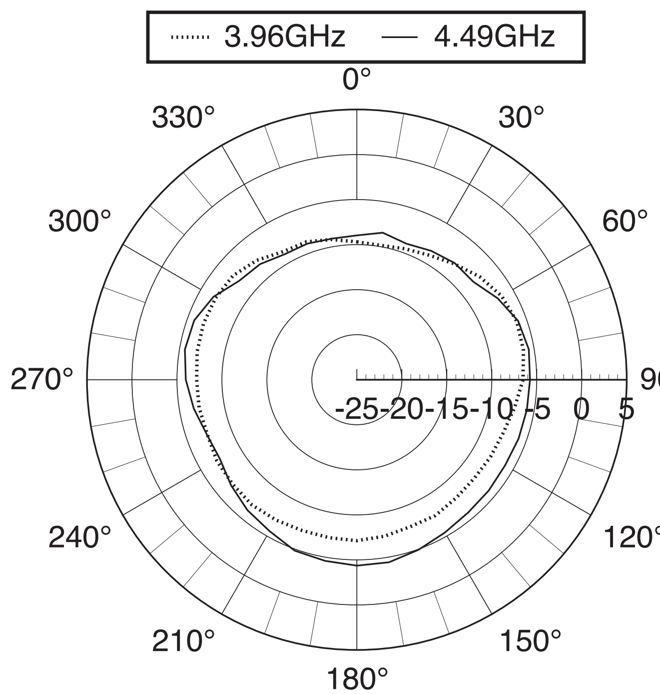


Fig. 9. E-plane cross-polarization radiation pattern of the metal powder mixed antenna ($z$-pol in $xy$-plane).


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