Live Wire

Researchers designed an unusually compact wearable antenna that covers the entire instrument, scientific and measurement band.

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A wireless body area network (WBAN) consists of a network of computing devices worn on the body that communicate with a server over a wireless network. WBANs can interact with sensors that monitor the wearer's medical status and provide an early warning of health problems (and this is only one application of the technology). Traditionally in WBAN design, circularly polarized (CP) microstrip patch antennas are used, since they can maintain performance in spite of movement by the wearer. However, CP antennas tend to have relatively narrow bandwidth. It is particularly difficult to obtain broad bandwidth with a compact CP antenna.

Researchers at Hanyang University set out to design a compact CP antenna with broad-enough bandwidth to cover the entire instrument, scientific and measurement (ISM) band, which runs from 2.4 GHz to 2.485 GHz. The antenna was designed as a square slot etched into the bottom plane of an FR-4 substrate with a pair of Y strips connected to ground with an inverted L-shaped microstrip feed line. A square slot is etched on the bottom plane of the 36 x 36 x 1.6 mm substrate with a relative permittivity of 4.4. To reduce the dimensions of the antenna, a portion of the inverted L-shaped feed line is meandered or folded over itself to provide the required resonant length but

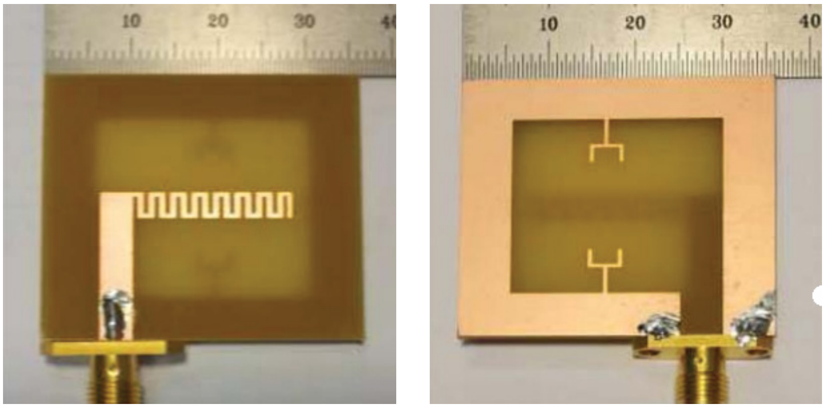
Researchers set out to design a compact CP antenna with a broad bandwidth.

within a smaller area. Other key design parameters include thickness of the feed line and width of each slotted section of the feed line. The research team considered adding strips connected to ground to broaden the 3 dB axial ratio bandwidth. They also considered I-shaped, T-shaped and Y-shaped strips.

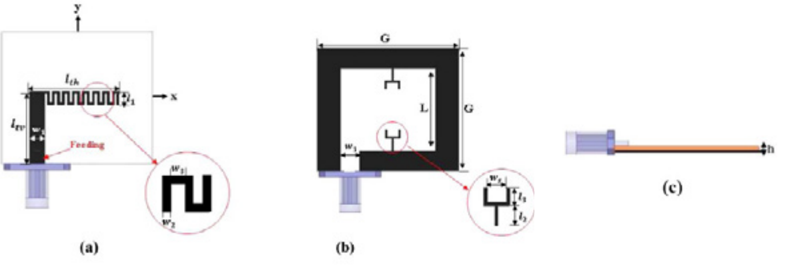
Researchers faced the challenge of configuring geometric parameters to optimize the antenna to achieve ideal return loss and axial ratio bandwidths. The return loss bandwidth consists of the frequency range over which the loss of signal power caused by the reflection at a discontinuity in the transmission line — such as mismatch with the terminating load — is below a certain value expressed in decibels. The axial ratio bandwidth is a measure of the quality of the circular polarization of the antenna. A circularly polarized field is made up of two orthogonal E-field components of equal amplitude that are 90 degrees out of phase. The axial ratio is the ratio of these components. The ideal value is 0 dB, and the axial ratio bandwidth is typically quoted as the bandwidth over which orthogonal components differ by no more than 3 dB.

Optimizing the design of the antenna using physical measurements is very time-consuming and expensive due to the high cost and long lead time involved in building each prototype iteration. So Hanyang researchers used ANSYS HFSS electromagnetic field simulation software to evaluate performance of the proposed antenna using a wide range of geometric parameters (listed below) prior to building hardware. They created basic parametric geometry by drawing it in HFSS and assigning material properties. By utilizing the integral automatic adaptive meshing capability of HFSS, they generated a mesh conformal to the 3-D structure and appropriate for the electromagnetic problem. Researchers assigned boundary conditions and excitations and then set up the analysis and frequency sweep. The final step was to run the simulation and view the results including antenna parameters.

The key parameters whose geometries were varied in the simulation were l_{th} (x-axis dimension of feed line), w_2 (thickness of feed line), w_3 (width of each slotted section of feed line), and w_s (distance between verticals on Y-strip), as shown in the diagram. The results for return loss



▲ Photograph of fabricated antenna including (left) top view and (right) bottom view



▲ Configuration of proposed antenna including (a) top view, (b) bottom view, and (c) side view. l_{th} = x-axis dimension of feed line, l_{tv} = y-axis dimension of feed line, w_2 = thickness of feed line, w_3 = width of each slotted section of feed line, w_s = distance between two tops of Y-strips.

l_{th} (mm)	w_2	w_3	10 dB Return Loss (GHz)
18	18	0	3.12 – 3.7
32	2	0.5	2.62 – 3.12
50	1	0.5	2.87 – 3.5
66	0.5	0.5	2.13 – 3.12

▲ Simulation predictions of return loss bandwidth for various l_{th} values

Strip	3 dB ARBW
No Strips	0
I-Shaped Strips	2.43 – 2.63
T-Shaped Strips	2.43 – 2.56
Y-Shaped Strips	2.15 – 2.8

▲ Simulation predictions of axial ratio bandwidth for different shaped strips

W_s (mm)	3 dB ARBW
3	2.3 – 2.7
3.5	2.2 – 2.8
4	2.15 – 2.8
4.5	2.55 – 2.65

▲ Simulation predictions of axial ratio bandwidth for various Y-strip widths

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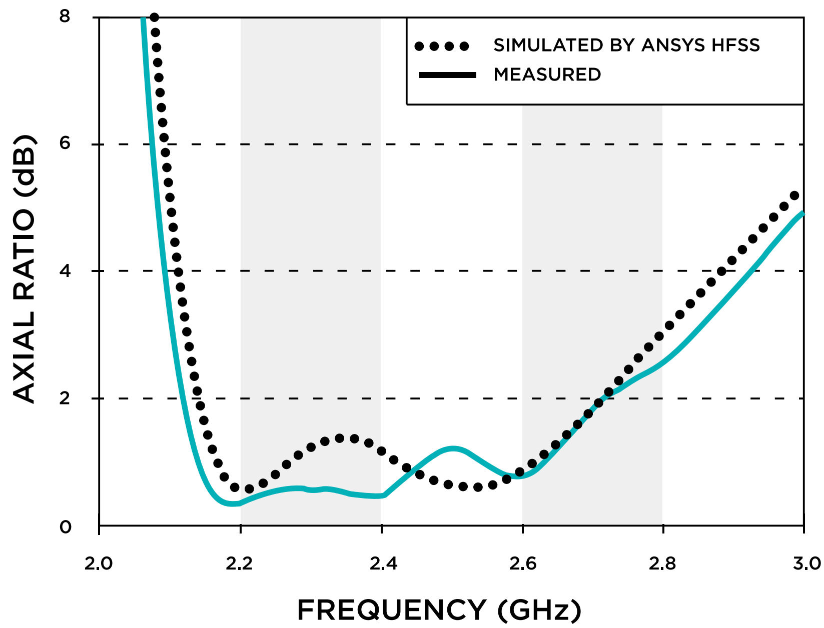
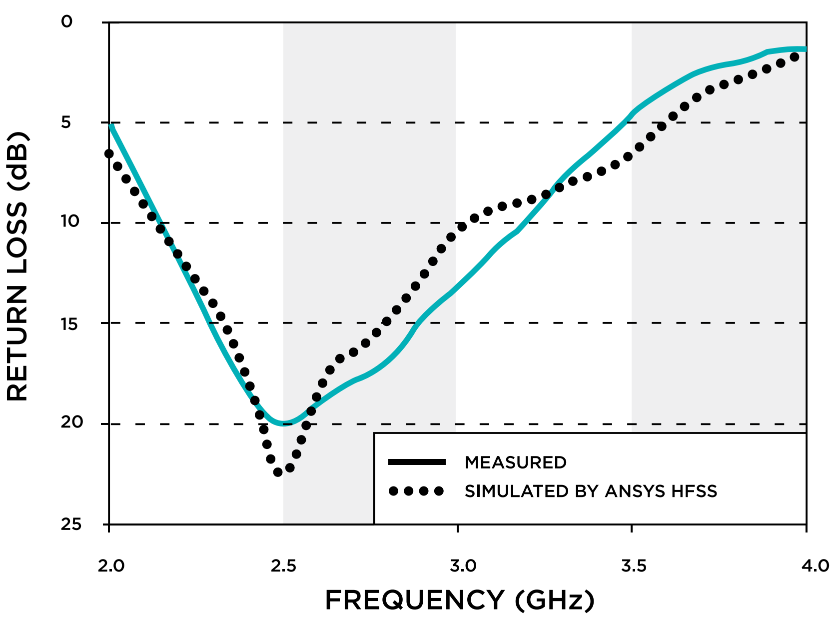


▲ Simulated and measured axial ratio of proposed antenna



▲ Simulated and measured return loss of proposed antenna

vs. frequency for different values of l_{th} show that the resonant frequency of the antenna is reduced as l_{th} increases. Based on these results, the proposed antenna uses Y-shaped strips, as it has the widest axial ratio bandwidth (ARBW): 3 dB. When w_s increases from 3 mm to 4.5 mm, the 3 dB bandwidth becomes wider. However, the enhanced axial ratio performance deteriorates as w_s becomes larger than 4 mm.

The proposed antenna was fabricated using the optimized design parameters determined through simulation: L (internal side length) = 24 mm, G (external side length) = 36 mm, l_{tv} = 19 mm, w_2 = 0.5 mm, w_3 = 0.5 mm, and w_s = 4 mm. The measured return loss characteristics of the fabricated antenna closely matched the simulation predictions. The antenna has a 10 dB return loss bandwidth of 1,120 MHz (from 2,170 MHz to 3,290 MHz) and a 3 dB ARBW of about 29 percent with respect to the center frequency of 2,450 MHz, which is wide enough to cover the full ISM band. The overall size of the antenna is small: 36 x 36 x 1.6 mm. The new antenna is more compact than similar antennas presented in the past, yet the bandwidth is broader. These features make this new antenna a good candidate for modern WBAN systems that require high performance, small size, low weight and low production costs. This optimized design may well be the catalyst for a wide variety of safe, comfortable body-worn devices for future medical and consumer product applications.

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