

Design of Dual-band Coupled-fed Dipole Array Antenna Element for PCL Systems

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Abstract—This article proposes a dual-band coupled-fed dipole array antenna element for Passive Coherent Location (PCL) systems, which is operating in FM and T-DMB bands. The proposed coupled-fed antenna is composed of the internal and external dipoles that resonate in FM and DMB frequencies, respectively. To confirm the suitability of the proposed coupled-fed antenna, we construct an 8-element uniform circular array (UCA) with the proposed coupled-fed dipole element and examine the beamforming performance of the array. The results verify that the proposed antenna structure can achieve the required dual-band operation for PCL systems using the coupled-fed mechanism.

Index Terms— Passive Coherent Location, dual-band dipole, coupled-fed structure, circular array antenna.

I. INTRODUCTION

Passive Coherent Location (PCL) systems are bistatic radars using different types of commercial radio frequency signals as illuminators such as FM-radio, analog TV, digital TV, and mobile communications. Since the PCL system only requires the receiving system, it has advantages of lowering overall system cost and at the same time effectively concealing the observation site. This PCL system can use multiple observation and illumination sites to improve accuracy, and the benefits of detecting low RCS stealth targets are also well known recently [1-2]. Because PCL systems use amplitude and phase delay information at each antenna port, individual antenna characteristics are one of the key factors in terms of overall system performance [3]. However, while most of previous studies have focused on signal processing, little research has been conducted on improving characteristics of individual antenna elements for PCL systems [4].

In this paper, we propose a novel design of an array antenna element that can achieve multiple matching frequency bands by applying a coupled-fed technique to a dipole antenna. This coupled-fed technique, often used for broadband matching characteristics of microstrip patch antennas [5-6], is first applied to the dipole antenna for PCL systems. The antenna element is composed of an internal dipole and an external coupled-fed dipole. These internal and external dipoles are fixed by the housing structure that employs the circuit board of a balun. Using the coupled-fed structure, the two adjacent resonances are properly controlled to achieve FM and DMB dual-band resonance characteristics. To confirm the effectiveness of the proposed design, we

fabricate the coupled-fed dipole element and measure the antenna characteristics, such as the reflection coefficient and the antenna gain. The proposed antenna element is then extended to an 8-element circular array, and the beamforming performance of the array is examined. The results demonstrate that the proposed coupled-fed dipole can increase the illuminators of opportunity compared with the conventional basic dipole array through improved dual-band operation.

II. Dual-band Coupled-fed Dipole Antenna

The geometry of the proposed dual-band dipole antenna with an electromagnetic coupling feed mechanism is shown in Fig. 1. The antenna is composed of internal and external dipoles with radii of R_{in} and R_{out} , respectively. The feed of the internal dipole is connected to the circuit board mounted with a balun (ADT1.5-1+), while the external dipole is coupled indirectly from the internal dipole. In this work, the coupled-fed structure is first employed to the dual-band dipole antenna. This coupled-fed technique for the dipole element can dramatically improve the matching characteristics, which increases the illuminator of opportunity for PCL systems. The lengths of the internal and external dipole radiators are denoted by H_{out} and H_{in} , respectively, which can control the resonance frequency. The resonance characteristics can also be related to parameters of R_{in} and R_{out} . In order to extract the optimal parameter values of the proposed antenna, the FEKO EM simulator [7] and a genetic algorithm [8] were used. The detail parameters are shown in Table I.

TABLE I. PARAMETERS OF THE PROPOSED ANTENNA

Parameters	Value
H_{out}	460 mm
H_{in}	670 mm
R_{out}	62.5 mm
R_{in}	15 mm

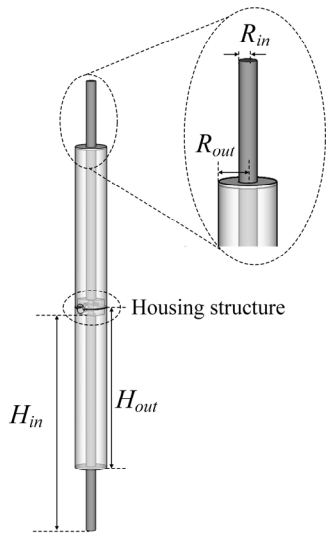
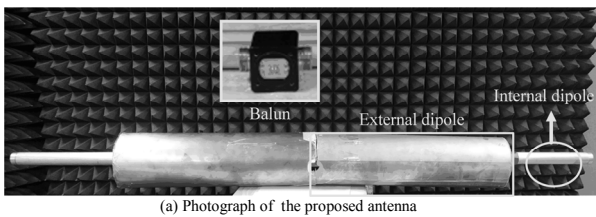


Fig. 1. Geometry of the proposed antenna.

Fig. 2 shows photograph of the proposed antenna and the outdoor test setup. The proposed antenna and the housing including the balun are shown in Fig. 2(a). The screw type connectors firmly fix the two internal dipoles to the housing. The radiation characteristics of the fabricated antenna were measured at an outdoor test setup of the CIS16-1-5 standard as shown in Fig. 2(b).



(a) Photograph of the proposed antenna



(b) Outdoor test setup

Fig. 2. Photograph of the proposed antenna and outdoor test setup.

Fig. 3 shows the VSWR of the proposed coupled-fed dipole antenna and reference dipole, where the solid, dashed, and dotted lines correspond to the measured results of the proposed antenna, the simulated results of the proposed antenna, and the simulated results of the reference dipole antenna. The FM and DMB region are represented with square gray color. There is an additional resonance from the external radiator in the 2nd gray DMB region. The proposed antenna shows good matching characteristics in FM and DMB bands, which is ranging from 88 MHz to 219MHz (VSWR < 3).

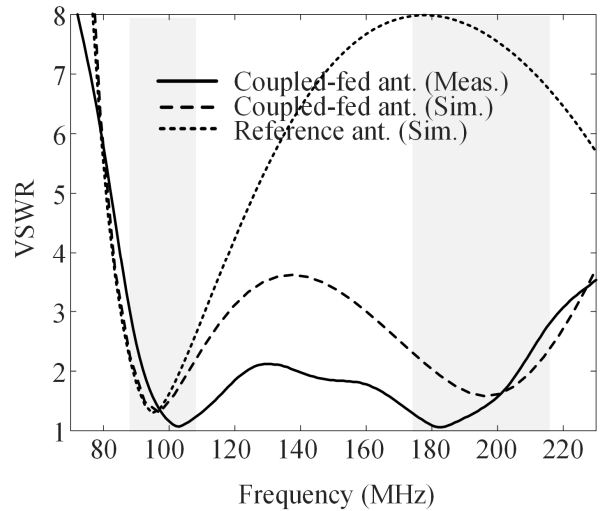


Fig. 3. VSWR of the proposed antenna and single dipole.

Fig. 4 shows the simulation bore-sight gains of the proposed and the single dipole antennas. The results of the proposed antenna are 2 dBi and 2.9 dBi at 100 MHz and 200 MHz, while the results of the reference antenna is 1.9 dBi and -0.2 dBi.

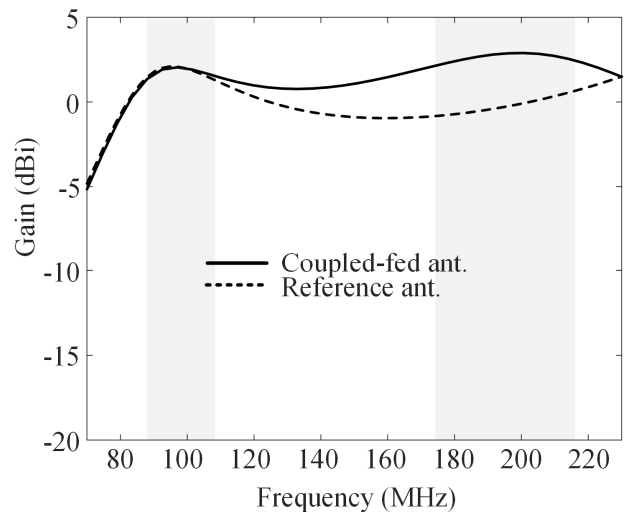


Fig. 4. Bore-sight gains of the proposed antenna and single dipole.

III. BEAMFORMING WITH THE PROPOSED ARRAY

To confirm the suitability of the proposed coupled-fed antenna, we constitute the 8-element uniform circular array (UCA) with the proposed coupled-fed dipole element and check the beamforming performance of the array as presented in Fig. 5. The array radius is $0.5\lambda_0$ from center to each antenna element. In Table 2, the detailed parameters for the array are listed. The PCL system checks the correlation between reference and surveillance channels to detect targets. In the reference channel, the beam pattern steers to a base station to obtain the commercial broadcast signals, and in the surveillance channel, the radiation pattern with deep null toward the base station is formed to check the echo signals reflected from the target. Therefore, the beamforming characteristics for steering and nulling are major performance for the PCL system.

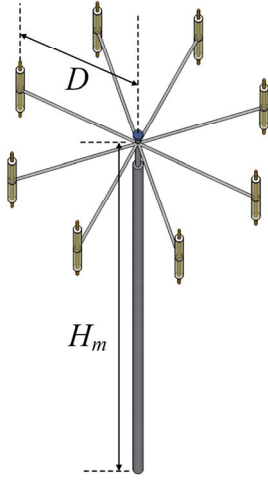


Fig. 5. 8-element UCA with the proposed coupled-fed dipole element.

TABLE II. PARAMETERS FOR ARRAY CONFIGURATION.

Parameters	Value
Number of array element	8
Array distance (D)	$0.5\lambda_0$
Mast height (H_m)	8 m
Array type	UCA

Figs. 6 and 7 illustrate the reference and surveillance beams at the FM center frequency of 100 MHz for azimuth angle of 0° , 45° , and 60° . The optimized beam patterns for the configured array structure is obtained from the least-mean-square (LMS) algorithm to make a narrow half-power beamwidth (HPBW) and deep null depth. The mean peak to side lobe ratio (PSLR) of the reference beam is 8 dB while the mean null depth of the surveillance beam is 17 dB.

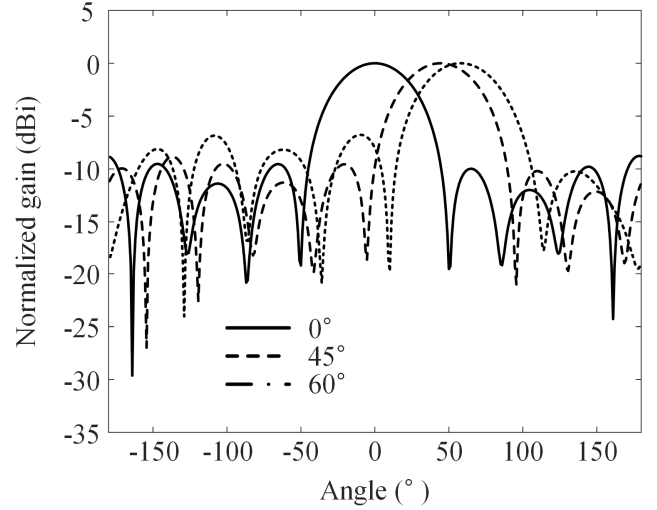


Fig. 6. Azimuth normalized pattern of the reference beam.

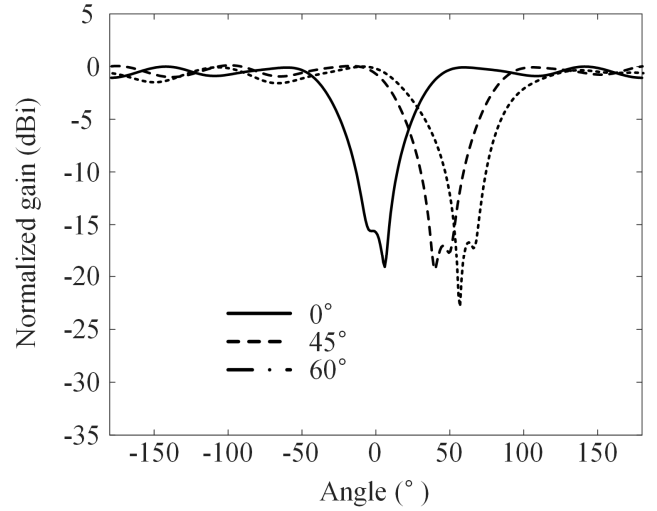


Fig. 7. Azimuth normalized pattern of the surveillance beam.

IV. CONCLUSIONS

We have investigated the design of the dual-band coupled-fed dipole antenna. The proposed antenna was composed of the internal and external dipoles, and the external dipole was electromagnetically coupled to the internal dipole for dual-band characteristics. The simulated frequency range for $VSWR < 3$ of the proposed antenna was from 88 MHz to 219 MHz. The bore-sight gains were 2 dBi and 2.9 dBi at each operating center frequency of 100 MHz and 200 MHz, respectively. The results demonstrated that the proposed antenna for PCL systems can achieve the dual-band operation with broadband matching characteristics using the coupled-fed mechanism.

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