



Fig. 1. System model.

finally, our paper is concluded in Section VI.

Notations: In this paper, boldface upper letters, boldface lower letters, and lower letters denote matrices, vectors, and scalars, respectively. $\mathbb{C}^{x \times y}$ and $\mathbb{R}^{x \times y}$ represent the set of complex matrices and real matrices with the dimension of $x \times y$, respectively. $|x|$ represents the amplitude of a complex number x . $\|x\|$ and $\|x\|_1$ denote the 2-norm and 1-norm of a vector x , respectively. The notation $(\cdot)^T$ and $(\cdot)^H$ refer to the transpose and the conjugate transpose of a vector or matrix, while \mathbf{E} represents the expectation operator.

II. SYSTEM MODEL

As shown in Fig. 1, we consider a multiple FAs assisted IDET system, which is comprised of a transmitter, a DR and an ER. The transmitter is equipped with N_t FAs, each of which has the same size and parameters without loss of generality. The DR and ER are both equipped with a single traditional antenna due to the limited hardware space. We assume that the transmit antennas are far apart in space and the channels of different antennas are fully independent, while the channels among different ports in the same antenna are strongly spatially correlated. The set of FAs and FA's port are denoted by $\mathcal{N}_t = \{1, \dots, N_t\}$ and $\mathcal{N} = \{1, \dots, N\}$, respectively.

A. Fluid antenna model

In this paper, we consider the practical architecture of the liquid metal-based fluid antenna. The length of fluid antenna is $W\lambda$, where λ is the wavelength of RF signal and W is a scaling constant. The MEMS is adopted in each fluid antenna to drive the metal droplet to move. Specifically, due to the electrocapillary effect, the motion of metal droplet is achieved by applying a voltage gradient along the FA, resulting in a phenomenon known as continuous electrowetting [24]. According to [5], the average velocity of the metal droplet motion is given by

$$u = \frac{q}{6\mu} \frac{D}{L} \Delta\phi, \quad (1)$$

where q is the initial charge in the electrical double layer for EGaIn, μ denotes the viscosity of EGaIn, D and L are the thickness and length of metal droplet, respectively. $\Delta\phi$ represents the voltage differential resulting from the flow of current through the narrow electrolyte layer between EGaIn and the wall, which is much smaller than the voltage U applied

between two ends of the FA [25]. Therefore, the moving delay from i -th port to j -th port can be expressed as

$$\tau = \frac{W\lambda}{u} \frac{|i-j|}{N-1}. \quad (2)$$

B. Wireless channel model

The block fading channel model is assumed between the transmitter and receivers, implying that the channel remains constant during a coherence time T but varies from one frame to another. Since the ports are located much closer in the same FA, strong correlation exists between the channels of different ports. Following Jake's two dimensional correlation model [26], the correlation between any two ports can be represented by a matrix \mathbf{J} , which is given by

$$\mathbf{J} = \begin{bmatrix} J_{1,1} & J_{1,2} & \cdots & J_{1,N} \\ J_{2,1} & J_{2,2} & \cdots & J_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ J_{N,1} & J_{N,2} & \cdots & J_{N,N} \end{bmatrix}, \quad (3)$$

where $J_{i,j} = J_0\left(\frac{2\pi(i-j)}{N-1}W\right)$ and $J_0(\cdot)$ is the zeroth-order Bessel function of the first kind. The channels between i -th FA and DR and ER in the t -th block are denoted as $\mathbf{h}_i(t)$ and $\mathbf{g}_i(t)$, which can be modeled as

$$\begin{aligned} \mathbf{h}_i(t) &= \sqrt{\frac{1}{PL_{h,i}}} \mathbf{U} \sqrt{\Lambda} \mathbf{z}_h(t), \\ \mathbf{g}_i(t) &= \sqrt{\frac{1}{PL_{g,i}}} \mathbf{U} \sqrt{\Lambda} \mathbf{z}_g(t), \end{aligned} \quad (4)$$

where $PL_{h,i}$ and $PL_{g,i}$ are the path-loss from i -th FA to DR and ER, respectively. \mathbf{U} and Λ are a unitary matrix composed of the eigenvectors of \mathbf{J} and a diagonal matrix consisting of the eigenvalues of \mathbf{J} , which satisfy $\mathbf{J} = \mathbf{U}\Lambda\mathbf{U}^T$. In addition, $\mathbf{z}_h(t) \in \mathbb{C}^{N \times 1}$ and $\mathbf{z}_g(t) \in \mathbb{C}^{N \times 1}$ are complex Gaussian random vector with each element having zero mean and variance of 1.

On the other hand, the channels of different transmission frames are temporally correlated, which can be expressed as

$$\begin{aligned} \mathbf{h}_i(t) &= \rho \mathbf{h}_i(t-1) + \sqrt{\frac{1-\rho^2}{PL_{h,i}}} \boldsymbol{\delta}, \\ \mathbf{g}_i(t) &= \rho \mathbf{g}_i(t-1) + \sqrt{\frac{1-\rho^2}{PL_{g,i}}} \boldsymbol{\delta} \end{aligned} \quad (5)$$

where ρ is the temporal correlation factor and $\boldsymbol{\delta} \sim \mathcal{CN}(0, \mathbf{I}_N)$ is the random difference with an identity matrix \mathbf{I}_N .

C. Signal model

Before the transmitter delivering wireless signal to the DR and ER, an appropriate antenna port should be selected on each FA. Assuming that the initial port of i -th FA is $k_{i,0}(t)$ in the t -th block, the port switching delay on the i -th antenna from the initial port to the selected port $k_i(t)$ is expressed as

$$\tau_i(t) = \frac{W\lambda}{u} \frac{|k_i(t) - k_{i,0}(t)|}{N-1}. \quad (6)$$