Recent Progress in Surface Wave Fluid Antennas

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Background: This paper reports the recent progress in using surface wave fluid antennas to improve multiplex gain and outage probability in mobile communications. Surface wave fluid antennas have been recently proposed to solve fading and interference problems in 5G mobile communications [1], [2]. Theoretical results showed that noticeable improvements can be obtained. In this paper, a channel model verified by extensive simulation and measured results have been developed for optimizing problems in a downlink Fluid Antenna Multiple Access (FAMA) scenario. The single channel fluid antenna reported in [3] is used, its radiation patterns at 21 fluid radiator positions at 26 GHz have been measured and used in the model.

Channel Model: To model the signal from different angle-of-arrival (AoA), we use the rich scattering channel model in [4]. The channel is modelled with a specular component (i.e., LoS) and N_p scattered components (i.e., non-LoS)

$$h_{j,i}{}^{(k)} = \sqrt{\frac{K\Omega}{K+1}}\, e^{j\alpha_{j,i}} e^{-j\frac{2\pi(k-1)W}{N-1} cos\theta^0_{j,i}} + \sum_{l=1}^{N_p} \alpha^l_{j,i}\, e^{-j\frac{2\pi(k-1)W}{N-1} cos\theta^l_{j,i}}. \tag{1}$$

where $h_{i,j}{}^{(k)}$ denotes the channel from the *j*-th antenna of base-station to the *k*-th port of the *i*-th user (UE), *K* is the power ratio between the specular and scattered components, $\alpha_{j,i}$ is the random phase of the specular component, $\alpha^l_{j,i}$ is the random complex coefficient of the *l*-th scattered path, $\theta^0_{j,i}$ and $\theta^l_{j,i}$ denotes the AoA of the LoS and the *l*-th non-LoS from the *j*-th antenna of BS to the *i*-th UE respectively , $E[|h_{j,i}{}^{(k)}|^2] = \Omega$ and $E[\sum_l |\alpha^l_{j,i}|^2] = \frac{\Omega}{K+1}$. Consider the radiation pattern of fluid antenna, the received channel at the UE is,

$$g_{j,i}{}^{(k)} = \sqrt{\frac{K\Omega}{K+1}}\, e^{j\alpha_{j,i}} e^{-j\frac{2\pi(k-1)W}{N-1} cos\theta^0_{j,i}} \sqrt{Gain^k_{\theta^0_{j,i}}} + \sum_{l=1}^{N_p} \alpha^l_{j,i}\, e^{-j\frac{2\pi(k-1)W}{N-1} cos\theta^l_{j,i}} \sqrt{Gain^k_{\theta^l_{j,i}}}, \tag{2}$$

where $Gain^k_\theta$ denotes the antenna gain in the direction of θ at the *k*-th port of fluid antenna.

Results: Over 1,000,000 channel realizations with K=20, $\Omega = 1$, $N_p = 5$ and fluid antenna with length 9.5mm (1.2λ) and 21 ports at 26GHz have been simulated. For fixed-position antenna, it locates at any one of the 21 ports. Therefore, we demonstrate the result of fixed-position antenna by randomly selecting a port. To show the benefits of fluid antenna, we compare the results of selecting the port with largest SINR and random port selection. We define an outage event if the SINR of user is below the target γ. Then the outage probability is defined as $\mathrm{Prob}(\mathrm{SINR} < \gamma)$. The multiplexing gain of the system is defined as the capacity scaling factor, which is given by,

$$m = M\big(1 - \mathrm{Prob}(\mathrm{SINR} < \gamma)\big) \tag{3}$$

where *M* is the number of UEs in the system.

Discussion: From Figure 1, we can observe that as the number of UE increases, the UE receives more interference, so the SINR decreases, and the outage events happens more frequently. When there are 2 users in the system, the outage probability of random port selection is 0.5, and it reduces to 0.15 (measurement) with desired port selection.

For multiplexing gain, 2 or 3 UE cases show the best performance in multiplexing gain (about 1.7). As the number of users increases, there is more interference in the system. The multiplexing gain of multi-users cases reduces since the outage probability reduces for more users' scenarios. Overall, the multiplexing gain is enhanced by selecting the port with maximum SINR compared to random selection.

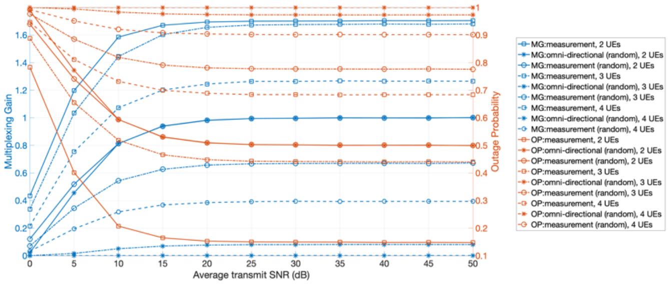

Figure 1. Multiplex gain and outage possibilities of the single channel fluid antenna in FAMA

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