WI-VI TECHNOLOGY

[1]Prerna Garg, [2]Shikha

[1,2]UG, Department Of Electronics and Communication Engineering,

Raj Kumar Goel Institute of Technology for Women. Ghaziabad (India)

ABSTRACT

Wi-Fi signals are typically information carriers between a transmitter and receiver. Through this paper we are trying to extend our senses so as to see moving object through the walls and closed doors, under this technology communication is possible by combination of gestures and by messaging without even using the any transmitter. In this paper to innovations are being introduced: (1) Use of MIMO interfacing to nullify the effect of static object and focusing the receiver on a moving target (2) motion of a human body is treated as an antenna and resulting RF beam is tracked. Not much research has been done on this technology but Wi-Vi could be built into a smart phone or a special handheld device and used in search-and-rescue missions and law enforcement. To exemplify, someone walking outdoors at night who thought they were being followed might use it to detect a person behind a fence or around a corner. The key benefits of Wi-Vi over current ways of seeing through walls, such as radar and sonar, are cost, power and size. At the heart of the technology is its encoding scheme, which can be implemented in silicon. Wi-Vi could be built into a cell phone soon, and for not much more than the cost of a regular Wi-Fi module. Bringing wall-penetrating vision to handheld devices could open up a lot more uses for it. Current radar-based systems used in the U.S. military are so big they need to be transported on trucks. Even the Army might need a more portable tool for seeing through walls in certain settings. Because of its low resolution, Wi-Vi could actually enhance people's privacy rather than erode it in some cases.

Keywords: Gesture-Based User Interface, MIMO, Wireless, Seeing Through Walls

I INTRODUCTION

The fantasies related to X-ray visions; comic books and sci-fi movies are finally being explored. This paper is mainly investigating about the Wi-Fi signals with the advanced MIMO communications by capturing the motions of humans behind the walls.

In this technology, the most challenging part is the reflections for the wall itself rather than reflections form the object. Due to reflection off the wall, minute variations coming through the object are prevented from being tracked.

This behavior of the object is known as "Flash Effect". Multi-GHZ transmission systems are required to sepa The objective of this paper is to enable a see-through-wall tech-nology that is low-bandwidth, low-power, compact, and accessible to non-military entities. To this end, the paper introduces Wi-Vi, a see-through-wall device that employs Wi-Fi signals in the 2.4 GHz ISM band. Wi-Vi limits itself to a 20 MHz-wide Wi-Fi channel, and avoids ultra-wideband solutions used today to address the flash effect. It also disposes of the large antenna array, typical in past systems, and uses instead a smaller 3-antenna MIMO radio.

Wi-Vi works by sending Wi-Fi radio waves through a barrier and measuring the way they bounce back. It's similar to the way radar and sonar work, but without the expensive, bulky gear and restricted frequencies that radar requires.Every time a Wi-Fi signal is reflected off an object, the shape and makeup of that object affects the signal that comes back. But when Wi-Fi hits a wall, most of the signal gets reflected off the wall and only a faint bit of it reflects off the people on the other side.

To get around this, Wi-Vi transmits two Wi-Fi signals, one of which is the inverse of the other. When one signal hits a stationary object, the other cancels it out. But because of the way the signals are encoded, they don't cancel each other out for moving objects. That makes the reflections from a moving person visible despite the wall between that person and the Wi-Vi device. Wi-Vi can translate those faint reflections into a real-time display of the person's movements.Wi-Vi's capabilities might also help searchers find people trapped in collapsed buildings after earthquakes. Police could use it to detect the number of people in a room and their movements, preventing an ambush when they raided the room. Used with a gaming console, it could allow players to walk away from the console into another room and keep playing the game.

II RELATED WORK

2.1 Through Wall Radar

Practicing on seeing through wall has been done for about a decade. In past time, inventers mainly focused on modelling and simulations. Recently few implementations have been tested with humans in moving position. Earlier system helped in stamp out the flash effect by isolating the reflected signal of the wall from the reflected signals of the objects behind the wall. This isolation can be achieved in time domain by using very short pulses (about 1 ns) due to which delay had been developed between arrival time of reflected signal off the wall and reflected signal off the moving objects behind wall. Isolation can also be achieved in frequency domain through linear frequency chirp. In this, reflections from objects at different position arrive with different tone. By doing analog filtering of tones corresponds to the wall may be leads to remove flash effects. All these techniques needs ultra-wide bands (UWB) of the order of 2GHz.And other through wall imaging product were based on radar principle which also need (UWB) and applicable for military purpose.

But wi-vi system has different characteristics as it requires law bandwidth, and operates in the same range as Wi-fi. Wi-vi overcome the requirement for the UWB by using MIMO nulling to remove flash effect.
Researchers found the limitations of UWB systems and give the concept of using narrowband radars for through

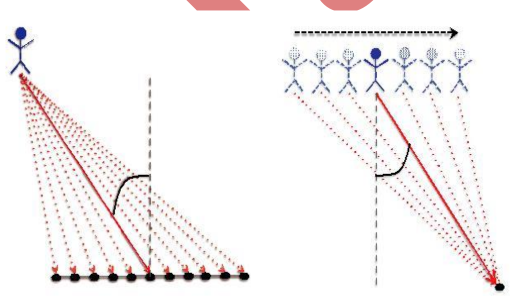
wall technology. These systems ignored the flash effect and tried to operate in high interference coused by the reflections off the wall They typically rely on Doppler shift caused by moving objects behind the wall. However, the flash effect limits their detection capabilities. Hence, most of these systems are demonstrated either in simulation [28], or in free space with no obstruction. . The ones demonstrated with an obstruction use a low-attenuation standing wall, and do not work across higher at-tenuation materials such as solid wood or concrete [29, 30]. Wi-Vi shares the objectives of these devices; however, it introduces a new approach for eliminating the flash effect without wideband trans-mission. This enables it to work with concrete walls and solid wood doors, as well as fully closed rooms. The only attempt which we are aware of that uses Wi-Fi signals in order to see through walls was made in 2012 [13]. This system required both the transmitter and a reference receiver to be inside the imaged room.
Furthermore, the reference receiver in the room has to be connected to the same clock as the receiver outside the room. In contrast, Wi-Vi can perform through-wall imaging without access to any device on the other side of the wall.

2.2 Gesture Based Interfaces

In today's time, commercial gesture recognition system such as the ninteudowii, xbox kinect etc. These system used to identify a variety of gesture. There are also such system those are capable of identifying human gestures by employing cameras or placing sensor on the human body. Recent work has also using narrowband signals in the range of 2.4 GHz to identify human activities in line of sight by using micro-doppler signatures. Wi-vi, however, presents the first gesture based interface which works in non line of sight scenarios & even through the wall and hence human is not require to carry a wireless device or wear a sensors on their body.

2.3 Infrared And Thermal Imaging

System based on infrared and thermal imaging extend the human vision beyond the visible electromagnetic range and allowing us to detect objects in presence of smoke & darkness. This system is operated by capturing infrared or thermal energy reflected from the first obstacle in line of sight of their sensors. But these technology does not allow us to see through walls due to having short wavelength (few µm to sub mm) , whereas wi-vi system having wavelength in the range of 12.5cm(3).



(a) Antenna Array **(b) ISAR**

Figure 1—A Moving Object as an Antenna Array. In (a), an antenna array is able to locate an object by steering its beam spatially. In (b), the moving object itself emulates an antenna array; hence, it acts as an inverse synthetic aperture.

III ELIMINATING THE FLASH EFFECT

Electromagnetic signal produces significant attenuation dense obstacles which leads to stronger flash signals than any other reflected signals off the object. Considering the tables above in which one way rf attenuation of signal is observed through wi-fi signal. For example- when the signal is travelled through interior hollow wall or concrete wall, the Wi-fi signal power is reduced by 9dB and 18dB.

As reflected signal on both the reflection coefficient as well as the cross-section of object due to which the actual reflected signal becomes weaker .hence, Wi-vi increases the sensitivity to the reflection of intrest by using the phenomenon of interference nulling.

3.1 Nulling To Remove Flash

Wi-Vi, however, avoids using an antenna array for two reasons:
First, in order to obtain a narrow beam and hence achieve a good resolution, one needs a large antenna array with many antenna elements. This would result in a bulky and expensive device. Second, since Wi-Vi eliminates the flash effect using MIMO nulling, adding multiple receive antennas would require nulling the signal at each of them. This would require adding more transmit antenna, thereby enabling the Wi-vi to capture the reflections from object of interest with minimal interference.
A few points are worth noting about wi-vi's procedure to eliminate the flash effect:-

- To eliminate the flash effect we have to remove reflected signal received from stationary objects both in front off and behind the wall and direct signals from transmitting antenna to receiving antenna.
- Wi-vi's uses nulling algorithm which provides a 42dB mean reduction in signal power which is enough to remove the flash effect.
- Nulling can be performed in the presence of objects moving behind the wall and front of the wall.

Table 1—One-Way RF Attenuation in Common Building Materials at 2.4 GHz

Building materials	2.4 GHz
Concrerte wall 18 inches	18dB
Solid wood door 1.75 inches	6dB
Interior hollow wall 6 inches	9 dB
Reinforced concrete wall	40 dB

IV IDENTIFYING AND TRACKING HUMANS

Since, we have eliminated the impact of static objects in the environment we can now focus on tracking of moving objects as humans.

4.1 Tracking a Single Human

In most advanced, through all systems antenna array is used to track the human motion. They steer the arrays beam to determine the direction of maximum energy and this direction corresponds to the signals spatial angle of arrival. By tracking that angle in time, we can infer how the object moves in space.

Wi-vi however, avoids using an antenna array due to following reasons:-

First, large antenna array is required to obtain a narrow beam and to achieve good resolution which would results in a bulky and costly device. Second, Wi-vi eliminates the flash effect using MIMO nulling, which require multiple receiving antennas that also makes the system even more bulky and expensive. To capture the benefits of antenna array and avoiding the drawbacks, Wi-vi introduces a new technique known as inverse synthetic aperture radar (ISAR). ISAR exploits the movement of the target to emulate an antenna array.ISAR uses only one receiving antenna which can capture a single measurement at any point in time. Because of channel reciprocity, successive time samples received by Wi-vi correspond to successive spatial locations of the moving target which thereby receives in time effectively. Emulation of the antenna array is achieved and using it for tracking motion behind the wall and treating the consecutive time samples as spatial samples. Let y[n] be the signal sample received by Wi-vi at a discrete time point n and θ is the spatial angle between the line connecting the human to wi-vi and normal to the motion fig 1[b].Here θ is positive when the vector from human to Wi-vi and vector of motion are in same direction and negative in opposite directions.

Now, we need to determine A[θ,n] a function that measure the signal along the spatial direction θ at time n. For determining this value,Wi-vi processes the received samples to remove the effect of transmitted signal and obtain the channel as:-

$$\boldsymbol{h[n] = y[n]/x[n]}$$

To emulate an antenna array of size w, it considers w consecutive channels i.e.,h[n].....h[n+w] as in fig[2]. By applying standard antenna array equations:-

$$\boldsymbol{A[\theta, n] = \sum_{i=1}^{w} h[n+i] e^{\frac{j2\pi}{\lambda} i\, \Delta \sin\Theta}}$$

Where, λ is the wavelength and Δ is the spatial separation between successive antennas in array.

To compute A[θ,n] from the above equation. We first need to estimate Δ.since, human motion emulates the antennas in the array, Δ=vT, where T is sampling period , v is the velocity of motion. Here, we can substitute v as comfortable walking speed (i.e.,1m/s). Without knowing v we cannot pin-point the location of human, but we can track the relative movement of human. Consider fig[3(a) and (b)] in which there are two lines , the first line is a zero line that represents the DC. This line is present regardless of the number of moving objects. Secondly, there is a curved line with changing angles.This line tracks the human motion . At n=0sec,the person starts moving towards Wi-vi device which makes the spatial angle θ positive and decreasing. At n=1.8s, the person crosses in front of Wi-vi device, at this time θ becomes zero.From n=1.8s to 3s, person is moving away fro Wi-vi device which makes the θ negative.

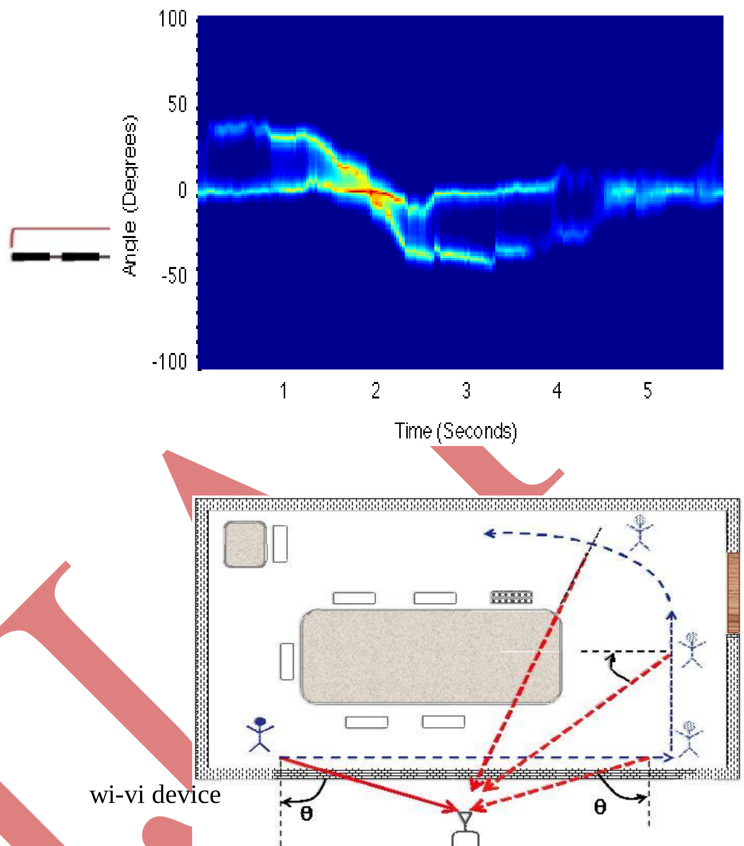


Figure 3—Wi-Vi tracks a single person's motion. (a) shows the experi-mental setup of a trial which consisted of a single person moving around in a conference room. (b) shows how Wi-Vi is able to track the motion of the person by computing the variation of the inverse angle of arrival with time, i.e. A'[θ, n] for θ in [−90°, 90°].

4.2 Tracking Multiple Humans

In this section, wi-vi used to track the extends its tracking procedure from single human to multiple human. As in our previous section, we considered the human motion as antenna array, therefore in multiple tracking, each human's motion will consider as separate antenna array. So the received signal will be in superposition of antenna arrays of multiple moving humans. Now this time, we will obtain number of curved lines instead of one curved line as moving humans at that point in time.

As there are multiple humans, therefore the noise increases significantly. On one hand, human body is not consider as one object due to having different body parts and as they are loosely coupled way. On other hand, the reflected signals coming from multi humans are correlated in time. As they all reflect the transmitted signals. The lack of interdependence between the reflected signals is most important. For example- the reflections of two humans may combine systematically to dim each other over some period of time.

The problem of disentangling correlated super-imposed signals is well studied in signal processing. The basic approach for processing such signals relies on the smoothed MUSIC algorithm. Similar to the standard antenna array processing, smoothed MUSIC computes the power received along a particular direction, which we call $A'[\theta, n]$,but in manner more resilient to noise and correlated sig-nals.

For a given antenna array of size w, MUSIC first computes the w ×correlation matrix R[n]:

$$\mathbf{R[n] = E[hh^H]}$$

Where H refers to the Hermitian (conjugate transpose) of the vector. It then performs an eigen decomposition of R[n] to remove the noise and keep the strongest eigenvectors, which in our case correspond to the few moving humans, as well as the DC value. For example, in the presence of only one human, MUSIC would produce one main eigenvector (in addition to the DC eigenvector). On the other hand, if 2 or 3 humans were present, it would discover 2 or 3 eigenvectors with large eigenvalues (in addition to the DC eigenvector). MUSIC partitions the eigenvector matrix U[n] into 2 subspaces: the signal space US[n] and the noise space UN[n], where the signal space is the span of the signal eigenvectors, and the noise space is the span of the noise eigenvectors. MUSIC then projects all directions θ on the null space, and then takes the inverse. This causes the θ's corresponding to the real signals (i.e., moving humans) to spike. More formally, MUSIC computes the power density along each angle θ as:

$$\boldsymbol{A'[\theta, n] = \frac{1}{\sum_{k=1}^{K} \| \sum_{i=1}^{w} e^{-\frac{j2\pi}{\lambda} i\Delta sin\theta} U_N[n](i,k) \|^2}}$$

Where k is the total no of noise eigen vectors.

In comparison to the conventional MUSIC algorithm described above, smoothed MUSIC performs an additional step before it computes the correlation matrix. It partitions each array h of size w into overlapping sub-arrays of size $w' < w$. It then computes the correlation matrices for each of these sub-arrays. Finally, it combines the different correlation matrices by summing them up before per-forming the eigen decomposition. The additional step performed by smoothed MUSIC is intended to de-correlate signals arriving from spatially different entities. Specifically, by taking different shifts for the same antenna array, reflections from different bodies get shifted by different amounts depending on the distance and orientation of the reflector, which helps de-correlating them.

Fig. 4 shows the result of applying smoothed MUSIC on the signal captured from two moving humans. Similar to Fig. 3(b), the y-axis corresponds to the angle, and the x-axis corresponds to time. As before, the zero line corresponds to DC. At any point in time, we see significant energy at two angles (besides the DC). For example, at time n = 0.5s, both humans have negative angles and, hence, are moving away from Wi-Vi. Between n = 1s and n = 2s, only one angle is present. This may be because the other human is not moving or he/she is too far inside the room. Again, from n = 2s to n = 3s, we see humans, one moving towards the device and the other moving away.

One point is worth emphasizing: the smoothed MUSIC algorithm is conceptually similar to the standard antenna array beam forming both approaches aim at identifying the spatial angle of the signal. However, by projecting on the null space and taking the inverse norm MUSIC achieves sharper peaks, and hence is often termed a super-resolution technique. Because smoothed MUSIC is similar to antenna array beam forming, it can be used even to detect a single moving object, i.e., the presence of a single person. Finally, to enable Wi-Vi to automatically detect the number of humans in a closed room, one option is to train a machine learning classifier using images like those in Fig. 3(b) and 4.

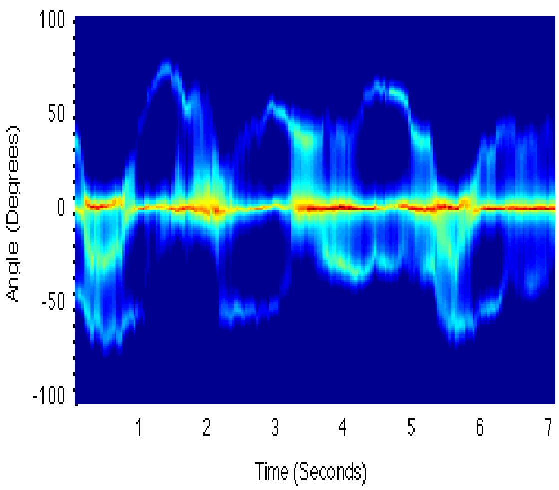


Figure 4—Wi-Vi tracks the motion of two humans. The figure shows how the presence of two humans translates into two curved lines whose angles vary in time, and one straight line which corresponds to the DC.

V THROUGH- WALL BASED GESTURE COMMUNICATION

Wi-vi has the ability in which human who does not carry any wireless device can communicate to receiver by using simple gestures. Wi-vi represents these pair of gestures by ‘0’ bit and ‘1’ bit. These gestures are later composed by human to create messages that are having different interpretations. Additionally, Wi-vi can develop by using other existing practices and principles such as adding a simple code that can ensure reliability, or by reserving a certain pattern of ‘0’ and ‘1’s. At this stage this technology is still very basic, yet we believe future advancements will make it more reliable and expressive. Gesture based through-wall communication is as follows:-

5.1 Gesture Encoding

At the transmitter side, encoding is performed by using some modulation scheme which is then implemented by the Wi-vi by using gestures. However, this encoding scheme is selected by imposing these conditions:-

- The gestures must be composable, i.e. at the end of each bit whether it is ‘0’ or ‘1’ human should be back in the same initial state as the start of gesture. This enables the human to compose multiple such gestures to send a longer message.

- The gestures must be simple so that human can easily perform and compose them.
- The gestures should be easily decoded without requiring any sophisticated decoders. By using above constraints we have selected a modulation scheme i.e. quite similar to Manchester encoding (where '0'bit is represented by falling edge and '1' bit is represented by falling edge of the clock).In this scheme '0' bit is a step forward followed by step backward and '1'bit is a step backward followed by step forward. These gestures are then easy to decode and compose.

In this the angle (θ) between the vector orthogonal to the motion and the line connecting the human to the Wi-vi device is detected. Taking a step forward towards Wi-vi devices produces a positive angle whereas taking a step backward produces a negative angle, the exact value of angle depends upon the human orientation towards the device i.e. the two angles +90° and -90°. However, if the human does not know the exact location of the wi-vi device and simply steps in its general direction, the absolute values of the angle is smaller but the shape of the bit is maintained.

5.2 Gesture Decoding

Decoding can be performed simply by using standard communication techniques. Hence, Wi-vi's decoder takes an input of A'[θ,n] and applies a matched filter to this signal. However, each bit is a combination of two steps i.e. forward and backward. So, Wi-vi applies two matched filter for each bit. According to the structure of the signal shown in fig.5 the two matched filters are simply a triangle above the zero line and an inverted triangle below the zero line which looks fairly like a BPSK signal , wi-vi applies these filters separately on the received signal and then adds up their output.

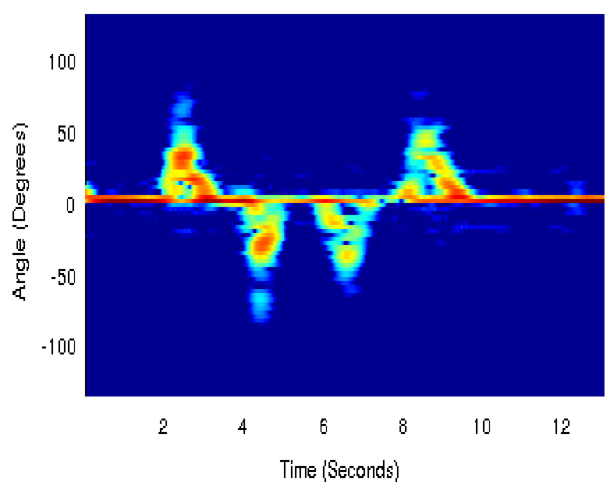
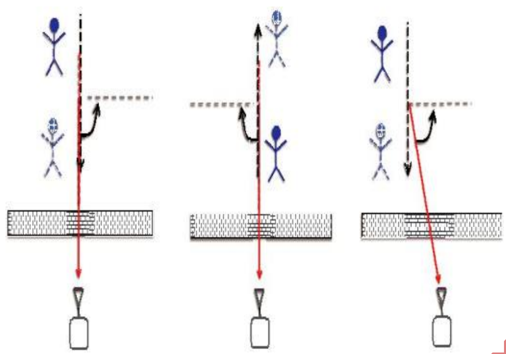


Figure 5—Gestures as detected by Wi-Vi. The figure shows a sequence of four steps: step forward, step backward, step backward, step forward. Forward steps appear as triangles above the zero line; backward steps appear as inverted triangles below the zero line. Each pair of steps represents a gesture/bit: the first two represent bit '0', the second two represent bit '1'.



(a) Forward (b) Backward (c) Slanted

Figure 6—Gestures as Angles. In (a), the subject takes one step forward; the emulated antenna array's normal forms an angle of 90° with the line from the human to Wi-Vi. Because the vector of the motion and the vector from the human to Wi-Vi are in same direction, θ is positive; hence, it is +90° . In (b), the subject takes a step backward, and θ = −90 degrees. In (c), the subject does not exactly know where the Wi-Vi device is, so he performs the steps towards the wall, without orienting himself directly toward Wi-Vi. Note that the vector of motion and the vector from the human to Wi-Vi are in the same direction; hence, θ is positive. However, due to the slanted orientation, it is now +60° (rather than +90°).

VI CONCLUSION

We present Wi-Vi, a wireless technology that uses Wi-Fi signals to detect moving humans behind walls and in closed rooms. In contrast to previous systems, which are targeted for the military, Wi-Vi enables small cheap see-through-wall devices that operate in the ISM band, rendering them feasible to the general public. Wi-Vi also establishes a communication channel between itself and a human behind a wall, allowing him/her to communicate directly with Wi-Vi without carrying any transmitting device. We believe that Wi-Vi is an instance of a broader set of functionality that future wireless networks will provide. Future Wi-Fi networks will likely expand beyond communications and deliver services such as indoor localization, sensing, and control. Wi-Vi demonstrates an advanced form of Wi-Fi-based sensing and localization by using Wi-Fi to track humans behind wall, even when they do not carry a wireless device. It also raises issues of importance to the networking community pertinent to user privacy and regulations concerning the use of Wi-Fi signals. Finally, Wi-Vi bridges state-of-the-art networking techniques with human-computer interaction. It motivates a new form of user interfaces which rely solely on using the reflections of a transmitted RF signal to identify human gestures. We envision that by leveraging finer nulling techniques and employing better hardware, the system can evolve to seeing humans through denser building material and with a longer range. These improvements will further allow Wi-Vi to capture higher quality images enabling the gesture-based interface to become more expressive hence promising new directions for virtual reality.

REFERENCES

[1] How Signal is affected. www.ci.cumberland.md.us/. City of Cumberland Report

[2] G. Char vat, L. Keppel, E. Roth well, C. Coleman, and E. Mohole. A through-dielectric radar imaging system IEEE Trans. Antennas and Propagation, 2010

[3] G. Char vat, L. Keppel, E. Rothwell C. Coleman, and E. Mohole. An ultra wideband (UWB) switched-antenna-array radar imaging system In IEEE ARRAY, 2010

[4] K. Chatty, G. Smith, and K. Woodbridge Through-the-wall sensing of personnel using passive bi static Wifi radar at standoff distances. IEEE Trans. Geosciences and Remote Sensing, 2012

[5] J. Choi , M. Jain, K. Sri Nivasan, P. Levis, and S. Katti . Achieving single channel, full duplex wireless communication,. In ACM MobiCom, 2010.

[6] G. Cohn,, D. Morris, S. Patel, and D. Tan. Hum antenna: using the body as an antenna for real-time whole-body interaction.

[7] H.Wang, R. Narayanan, and Z. Zhou. Through-Wall imaging of moving targets using uwb random noise radar. IEEE Antennas and Wireless Propagation Letters, 2009. J. Xiong and K. Jamieso

[8] A. Oppenheim, R. Schafer, J. Buck, et al. Discrete-time signal processing. Prentice hall Englewo

[9] S. Ram, C. Christianson, Y. Kim, and H. Ling. Simulation and analysis of human micro-dopplers in through-wall environments. IEEE Trans. Geo Science and Remote Sensing, 201od Cliffs, NJ:, 1989.n. Array Track: a fine-grained indoor location system. In Use nix NSDI

[10] Seeing through walls - MIT's Lincoln Laboratory. http://www.youtube.com/watch?v=H5xmo7iJ7KA2013.