Antennas with Wafer Transfer Technology: (A-WTT)

Himanshu Tyagi, Hamid Ali and Nitin Gupta

Abstract: - In this paper wafer transfer technology and the low temperature co-fired ceramic technology are employed for 60 GHz antenna designs. A coplanar waveguide fed coplanar strip dipole antenna using the WTT technology is presented. Meanwhile, two antenna arrays using the LTCC technology are reported.

Keywords: - antenna, WTT, antenna technology, LTCC.

I. INTRODUCTION

Antenna systems can play an important role in the improving communications system link performance. While advanced antenna technologies have been utilized extensively in the space and defense systems terrestrial based communication systems such as cellular have not utilized such advanced antenna systems. Recently, we have begun to see entrance of many former aerospace and defense systems contractors into weak less communications antenna markets. Many are looking to incorporate their own antenna technologies into wireless systems. Some systems are quite complex technically while others are more modest simple. This paper will provide an overview of some of most prevalent antenna technologies that are in process of transferring from high tech defense/aerospace industries into more commodities based wireless communications business. [2, 3]

II. ANTENNA TECHNOLOGIES

The antenna technologies discussed will be broken into two categories (1) smart antenna systems **(2)** antenna aperture technology and implementation. Smart antenna systems involve use of a feedback mechanism in which forward and reverse communication link is optimized by scanning mobile traffic at base station and making decisions on direction of arrival of signal. From processed information, we use a controller to direct antenna system to steer toward the best receive signal. Two basic approaches to smart antenna technology will be reviewed and some examples of performance demonstrated. Antenna aperture technology does not involve feedback and control systems but rather tries to improve upon performance of existing cellular antennas while making them more esthetically acceptable to local communities. Many approaches to implementation of diversity, antenna combining and antenna aperture design are also capable of providing link improvements. Several technology improvements, panel antennas, polarization and angle diversity schemes and beam combining will be discussed.

Himanshu Tyagi and,Hamid Ali are with IIMT Ganga nagar Meerut (U.P) INDIA and Nitin Gupta is with UCER college, Gr. NOIDA (U.P) INDIA, Emails: him.iimt@gmail.com,aman.155002@gmail.com

III. ANTENNA APERTURE TECHNOLOGY

Until recently, antenna aperture technology has not been an area with significant development. During the 1980s cellular companies deployed simple antenna apertures with little regard for esthetics or tower placement. This has resulted in a litany of the antennas on a tower and today typical cellular tower has a minimum of nine sector antennas and sometimes twelve at high traffic sites. These un slightly antennas have caused local communities to place moratoriums on cell site placement. Forcing PCS companies to rethink their strategy for tower and antenna installations. The primary concerns in new strategy are how do we place antennas on a tower as to minimize visual impact on community and can we improve antenna performance in process. The latter is of the great importance to service providers who see smart antenna technology as too expensive and complex a means by which to improve: their link budget. Improving antenna performance including the RF frontend is an alternative that if economical, would be embraced quickly. To improve the antenna performance we must increase its gain and efficiency, and/or improve upon diversity performance. Recall that in the traditional three sectored systems there are usually nine antennas. The receive antennas are horizontally separated several wave lengths apart to provide space diversity which typically results in a 10 foot spacing. This separation requirement unfortunately increases tower space necessary to accommodate the antennas. More desirable is an antenna configuration that provides an alternative to horizontal space diversity, having comparable diversity performance, increased antenna gain, better front-end signal to noise ratio (SNR), and not looking like an antenna (i.e. stealth or low profile). Spectrum around 60 GHz has recently received much attention because its unlicensed 7 GHz from 57-64 GHz band enables a high-speed internet, real-time video streaming, high-definition television wireless gigabit Ethernet, and automotive sensor with the wireless transmission data rate up to multi Gb/s [1]. In the 60GHz band, wireless communication systems require miniaturization, portability, cost-saving and performance improvement to satisfy specifications of next-generation multi-gigabit per second wireless transmission [2]. Traditional millimeter wave circuit devices are always mounted on high frequency organic substrate like Rogers RT/Duroid 5880. In printed circuit board or thick-film process, the precision control of dimension and roughness of pattern layer is poor. This causes high deviation from design specifications and inferior circuit reliability. To overcome drawbacks of PCB/thick-film process, wafer-transfer technology has been developed for high-performance circuit devices embedded on packaging substrates [3]. The WTT looks very promising as it offers unique feature of small

dimension of about 1 micrometer fabrication tolerance. On other hand, three-dimensional integration approach using multilayer low temperature co-fired ceramic technologies has emerged as an attractive solution for these systems due to its high level of compactness and mature multilayer fabrication capability. Many investigations have been devoted to 60 GHz antenna and array designs [4-8], where on-wafer measurements were usually employed. In this paper the coplanar waveguide fed coplanar strip dipole antenna using the WTT technology is presented. Meanwhile using LTCC technology a series fed antenna array with a vialess CPW to microstrip transition and an integrated 60 GHz antenna array with a conventional air-filled rectangular waveguide interface WR15 for easy measurement are reported. [4, 5]
[7]

WTT: - The WTT process is briefly described here. The sample is fabricated on an 8-inch low resistivity p-Si substrate using standard Cu backend of line technology with undoped silicon glass interconnect dielectric. A stack of SiO2 is deposited on Si substrate to serve as an etch-stop for Si removal. The top aluminium is patterned and etched to form test structures. The fabricated sample is next inverted and bonded to a plastic substrate. A grinding process followed by a final wet etching process is the performed. Fig.1 shows a CPW fed CPS dipole antenna fabricated using WTT technology. By careful design of hollow patch, optimum operating frequency range of transition from CPW to CPS can be achieved.

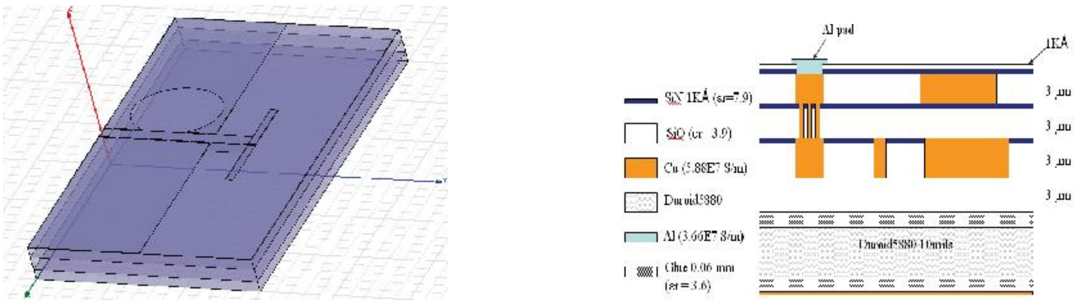

Fig. 1 WTT Dipole antenna

Fig. 2 shows simulated and measured |S11|. The difference between simulation and measurement could be due to inaccurate dielectric constant at 60 GHz given in simulation. The simulated 3D radiation pattern is illustrated in Fig.3. The truncated ground plane acts as a reflector to result in a unidirectional dipole pattern. The simulated gain is shown in Fig.4. A measured gain of 5.1 dBi at 60 GHz is also depicted in Fig.4. The antenna gain measurement setup on a probe station is shown in Fig. 5. The power meter was used to measure the receiving powers obtained from standard horn and antenna under test.

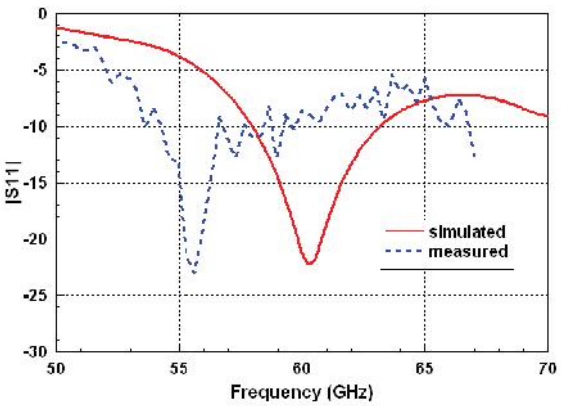

Fig. 2 Measured and simulated S11

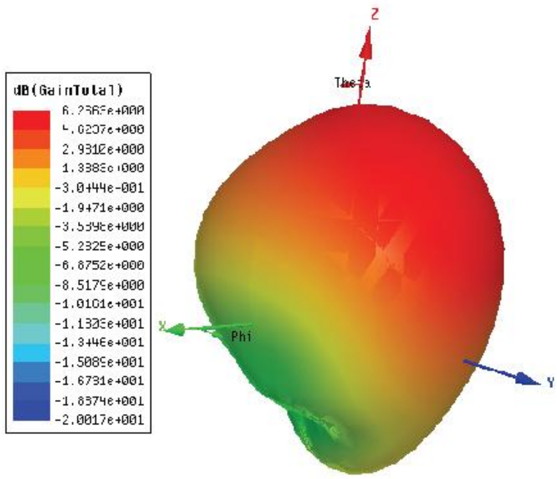

Fig. 3 simulated radiation pattern

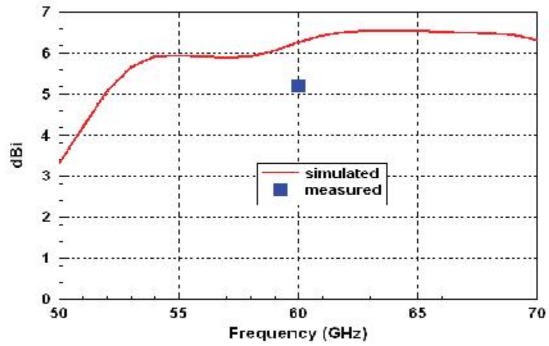

Fig. 4 Measured and simulated gain

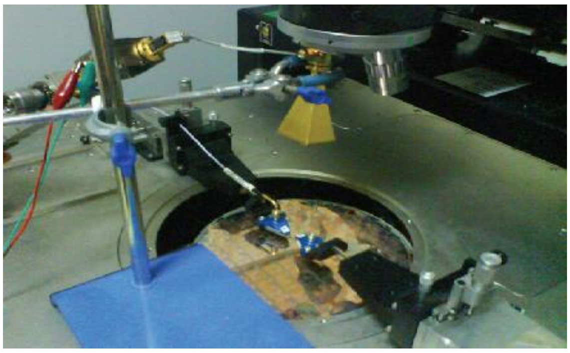

Fig. 5 Gain measurement setup

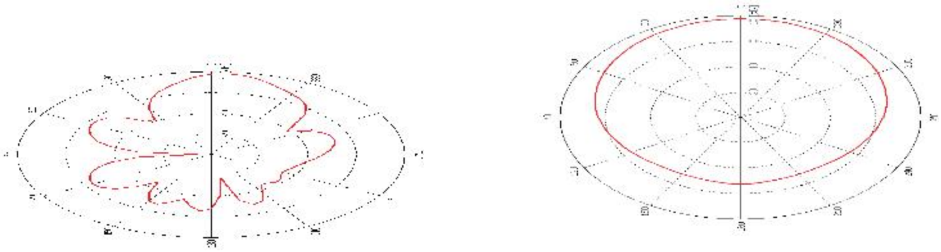

Fig.6 Simulated radiation patterns at 61.5GHz of the series array (a) E-plane, (b) H-plane

IV. LTCC INTEGRATED ANTENNA ARRAY

Fig.9 shows an LTCC integrated antenna array with an air filled RWG interface for easy measurement. It includes a broadband integrated transition between an LTCC substrate integrated waveguide and an air filled RWG WR15, a broadband integrated transition between an LTCC SIW and a microstrip line and a microstrip-line fed antenna array in LTCC. Fig. 10 exhibits the 3-D structure of the multilayer transition. An integrated Ka-band transition between an LTCC SIW and a WR28 waveguide was demonstrated in [8]. It has shown promising compact, low-loss and broadband features. The top and bottom layers of LTCC substrate are fully covered by metal, except a rectangular aperture on bottom layer. The aperture has the same size as inner cross section of air filled RWG WR15. As shown in Fig. 10, inside the LTCC substrate, separated by a partition conductive wall, two parallel SIWs are formed and excited by air filled waveguide. Similar to [8], part of metal strip in partition wall was removed to create mutual coupling between two parallel SIWs. The two SIWs are shorted at one end and connected to a single SIW on other end through a Y branch structure. An optimized Y branch is obtained through a numerical study performed with a soft HFSS. A WR15 wave guide is used in study as an air-filled waveguide whose cross-sectional dimension is 3.76 mm by 1.88mm. The SIW having a cross-sectional dimension of 1.88 mm by 0.5 mm is chosen by using five layers of Ferro A6 with εr = 5.9 and tanδ = 0.0028. Fig. 11 shows the simulated S parameters for an optimized transition between air-filled RWG and LTCC SIW. It is observed that broadband transition can cover from 54 GHz to 66 GHz. Figs. 7 and 8 show the simulated and measured return loss and bore sight gain for antenna array. The antenna array exhibits a simulated impedance bandwidth of 13.7%, from 58 to 66.53 GHz for return loss less than -10dB. The simulated bore sight gain is more than 12.8 dBi within impedance pass band and reaches a maximum of 14.2 dBi at 65 GHz. The measured results are slightly worse as measurement were conducted for antenna with all the transitions. Fig. 9 shows the simulated radiation patterns for antenna array at design center operating frequency of 62.5 GHz. A half-power beam width of 30o and a front-to-back ratio of 11.5 dB can be observed in both principle planes. [8]

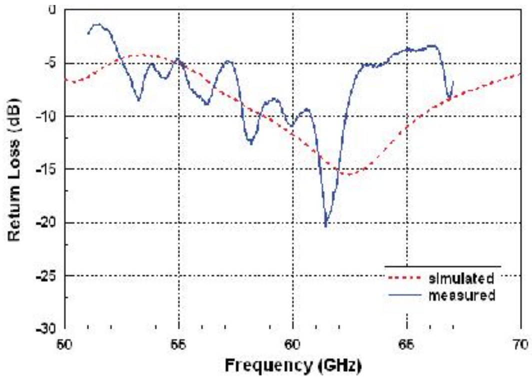

Fig. 7 |S11| for the antenna array

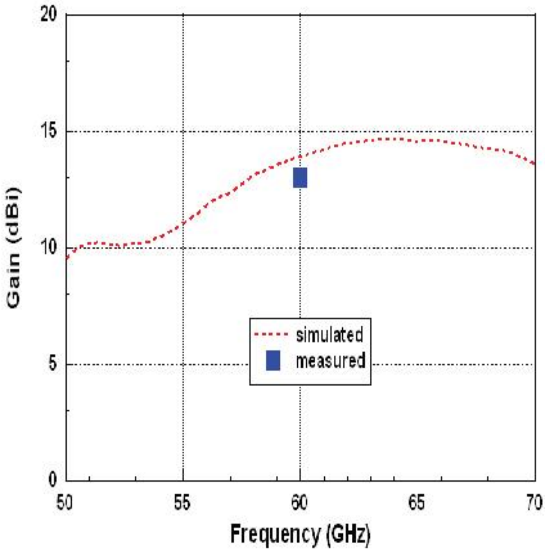

Fig. 8 Gain for the antenna array

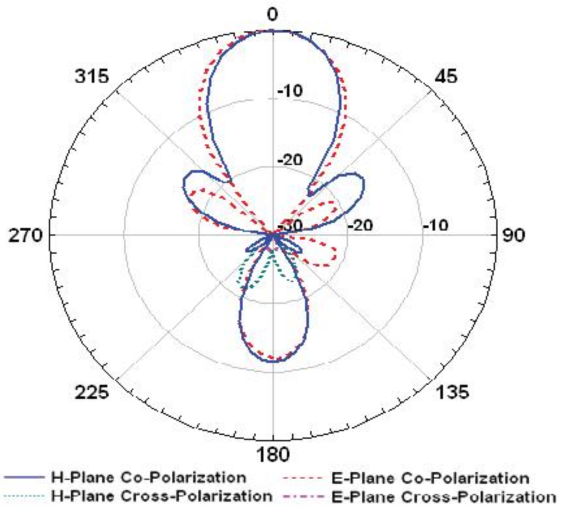

Fig. 9 Radiation patterns at 62.5 GHz

V. CONCLUSION

There are several important system issues, which were not discussed in this paper. More detailed discussion is needed for SA receiver integration into different types of cells, taking into consideration air interface specification. ST processing in CDMA requires more explicit discussion. In this paper wafer transfer technology and the low-temperature co-fired ceramic technology are employed for 60 GHz antenna designs. A coplanar waveguide fed coplanar strip dipole antenna using the WTT technology is presented.

REFERENCES

[1] C. H. Doan, S. Emami, D. A. Sobel, A. M. Niknejad, and R. W. Brodersen, “Design considerations for 60 GHz CMOS radios,” *IEEE Commun. Mag.*, vol. 42, no. 12, pp. 132–140, Dec. 2004.

[2] J.-H. Lee, G. DeJean, S. Sarkar, S. Pinel, K. Lim, J. Papapolymerou, J. Laskar, and M. M. Tentzeris, “Highly integrated millimeter-wave passive components using 3-D LTCC system-on-package (SOP) technology,” *IEEE Trans. Microw. Theory Tech.*, vol. 53, no. 6, pp. 2220–2229, Jun. 2005.

[3] L. H. Guo, Q. X. Zhang, G. Q. Lo, N. Balasubramanian, and D.-L. Kwong, “High-Performance Inductors on Plastic Substrate,” *IEEE Electron Device Lett.*, VOL. 26, NO. 9, Sept. 2005, pp. 619–621.

[4] T. Seki, N. Honma, K. Nishikawa, and K. Tsunekawa, “Millimeter-Wave High-Efficiency Multilayer Parasitic Microstrip Antenna Array on Teflon Substrate,” *IEEE Transaction on Microwave Theory and Techniques*, vol. 53, no. 6, June 2005, pp. 2101-2106.

[5] U.R. Pfeiffer, J. Grzyb, D.X. Liu; B. Gaucher, T. Beukema, B.A. Floyd, S.K. Reynolds, “A chip-scale packaging technology for 60-GHz wireless chipsets,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. 54, No. 8, Aug. 2006. pp. 3387 – 3397

[6] S. Pinel, Il K. Kim, K. Yang and J. Laskar, “60 GHz Linearly And Circularly Polarized Antenna Arrays On Liquid Crystal Polymer Substrate,” *Proceedings of 36th European Microwave Conference*, 10-15 Sept. 2006, pp. 858 - 861

[7] T. Zwick, D.X. Liu, B.P. Gaucher, “Broadband Planar Superstrate Antenna for Integrated Millimeterwave Transceivers,” *IEEE Transaction on Antennas and Propagation*, Vol. 54, No. 10, Oct. 2006, pp. 2790 – 2796

[8] Y.P. Zhang, M. Sun, K.M. Chua, LL. Wai, D.X Liu, “Integration of slot antenna in LTCC package for 60 GHz radios,” *Electronics Letters*, Vol. 44, No. 5, Feb. 2008, pp. 330 – 331.

Mr. Himanshu Tyagi received the B.Tech (Electronics & Communication Engineering) degree from RGEC College of Engg. & Technology, Meerut. Pursuing M.Tech. (2nd year) from Subharti University Meerut (U.P) currently, working as an Assistant Professor in IIMT Ganga nagar Meerut (U.P) INDIA. My research field is Microelectronics.

Mr. Hamid Ali received the B.Tech (Electronics & Communication Engineering) degree from IETE New Delhi in 2007. Pursuing M.Tech. (2nd year) from Shobhit University Meerut (U.P) currently, working as an Assistant Professor in IIMT Ganga nagar Meerut (U.P) INDIA. My research field is Micro strip Antennas.