

CHAPTER 4

MICROWAVE TECHNOLOGIES AND PROPAGATION MODELS FOR WIRELESS COMMUNICATION SYSTEMS

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INTRODUCTION

Microwave technology, with its multi-faceted applications and broad areas of impact, presents a critically important technology for enabling the development and optimization of next-generation wireless communication systems. It includes the design, fabrication, and packaging of high-frequency components and devices, the antenna technology, and the simulation and measurement aspects of communication channel sounding and propagation modeling. Potential areas of research and development include the development of new device architecture for integrated analog and digital components; implementation of the RF MEMS technology in the development of compact, low-power, high-efficiency devices; development of low-cost phased array antennas with beam-steering capabilities; innovative high-frequency 3D packaging technologies; new materials for high-frequency and high-power devices; an integrated CAD environment for the design and optimization of microwave and millimeter devices; and the development of accurate and computationally efficient propagation models. In this chapter, the panel will present observations and summarize findings in these areas from the site visits during the Asian Telecommunications Update.

SUMMARY OF OBSERVATIONS AND FINDINGS

To begin with, strong R&D activities and educational programs were observed at the National Taiwan University (NTU), National Chiao Tung University (NCTU), and the National Central University (NCU) in Taiwan and at the University of Hong Kong and the Hong Kong Science and Technology University. More focused programs in the ceramics and high-frequency packaging technologies were observed at the ITRI-CCL in Taiwan. Strong research activities were also suggested at both the Tsinghua University and the Beijing University of Posts and Telecommunications in mainland China, but focus in this report will be placed on the activities actually observed in both Taiwan and Hong Kong. Other visits to mainland China are suggested to report findings based on first-hand experiences and actual observations by panelists.

Observations from Visits in Taiwan

As indicated earlier, members of the panel observed strong and state-of-the-art microwave research activities at the NTU, NCTU, and NCU. These research activities will be summarized next, but it is interesting to note that much of the ongoing research is in areas of "available technologies" rather than in a far-reaching, down-the-road type of research. In other words, observed research was focused on short-term impact, addressing industrial and manufacturing needs, and on satisfying the phenomenal growth in the telecommunication market.

Examples of research at NTU

Microwave laboratory facilities include a microwave circuits lab for simulation, design, and fabrication of microwave circuits and high-frequency devices, an anechoic chamber (new) for antenna measurements and EMC characterization of devices, and a computational electromagnetics lab. Figure 1 shows the anechoic chamber at NTU, while Figure 2 shows the network analysis and probe station facilities. Examples of research projects include channel modeling and measurements, microwave and mm-wave circuit design, and antennas.

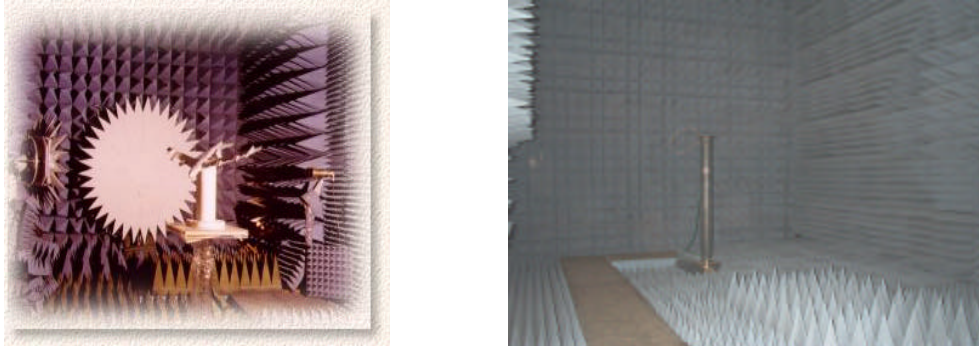


Fig. 1. Anechoic chambers for antenna measurement at NTU.



Fig. 2. Microwave network analysis and probe station lab at NTU.

Figure 3 shows one of the MMIC designs implemented in this lab. It is a 28-36 GHz three-stage, low-noise amplifier fabricated on a 5 mil ceramic. Characteristics include a gain of 15 dB and a noise figure of less than 3.5 dB. Figure 4 shows results from another project that involves design and characterization of a two-element scanning active array. The array is "phase-shiftless" and the novel contribution includes the use of a feedback-type active array and the mixing of the control line signal and mutual coupling to achieve steering. In another area of research that involves the biomedical application of microwave energy, the research team at NTU is developing an insulated coaxial slot antenna as shown in Figure 5. The operating frequency is 915 MHz, and the antenna is intended for use in hyperthermia applications.

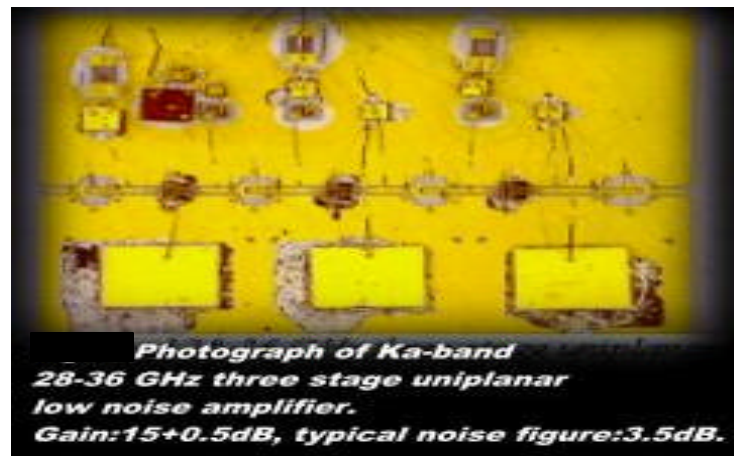


Fig. 3. A three-stage, low-noise mm-wave amplifier designed and fabricated at NTU. Characteristics include 28-36 GHz operating frequency, 15 dB gain, and 3.5 dB noise figure.

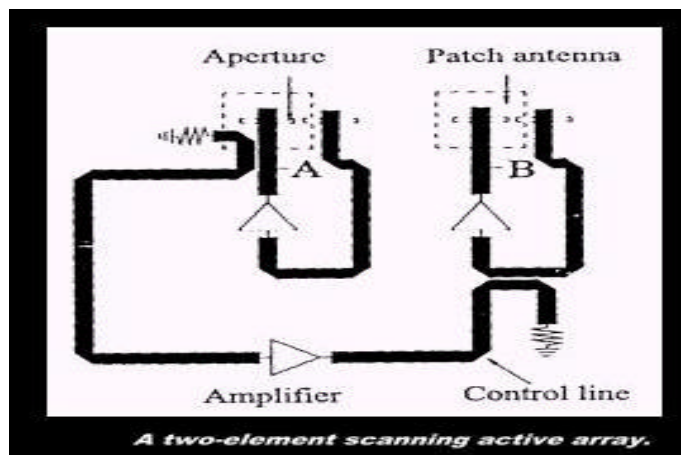


Fig. 4. A new phase-shiftless antenna array design at NTU.

As it may be seen, the facilities are state of the art and the research is innovative but in areas of available technologies.

Examples of research at NCTU

At the NCTU, outstanding research facilities were observed in the solid-state area. This is particularly true for the National Nano Device Laboratory with its extensive and state-of-the-art facilities. In the microwave area, the team was particularly impressed with the wideband vector radio channel sounding system. This \$500,000 system operates in the 5-6 GHz frequency range, provides periodic multi-frequency excitation $0.8 \text{ ms} < t_p < 25.6 \text{ ms}$, and its bandwidth is 120 MHz. Figure 6 shows a schematic of the system when connected to a multi-element antenna.

The microwave group also operates with a much larger center for wireless communication, and colleagues at NCTU shared with members of the panel some of the ongoing research projects. Much of it is in

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construction of hardware for transceivers, and educational activities were integrated as part of these projects. The team also visited an outstanding facility for multimedia development and distance learning.

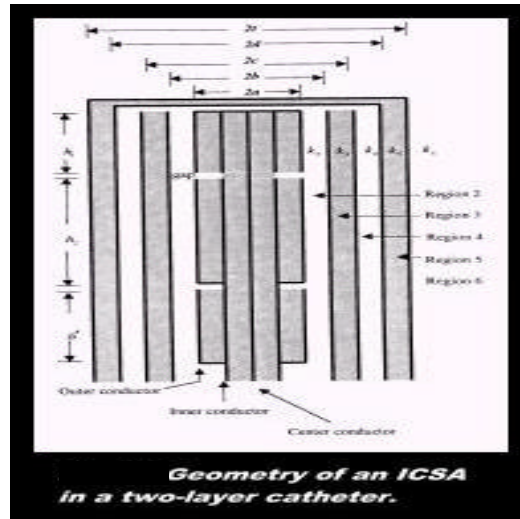


Fig. 5. A 915 MHz insulated coaxial slot antenna design for hyperthermia applications.

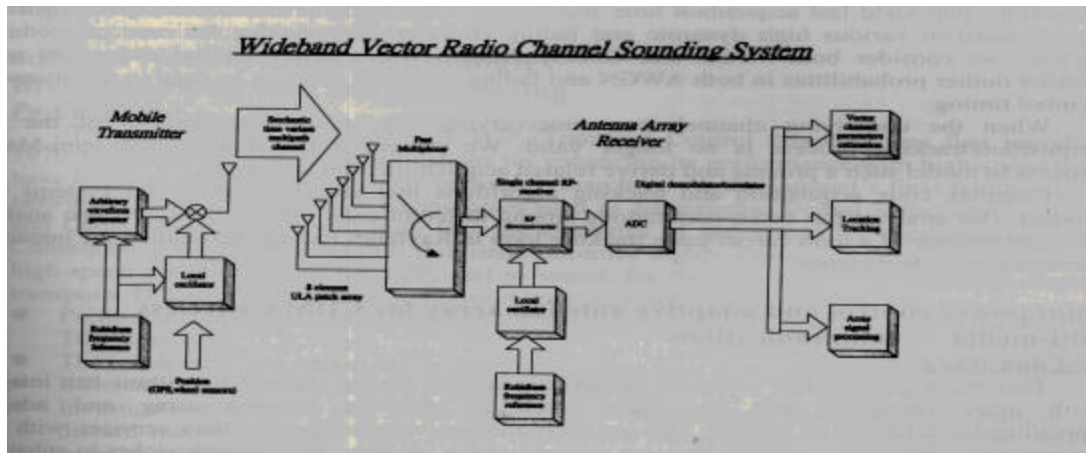


Fig. 6. Wideband vector radio channel sounding system at NCTU.

Examples of research at NCU

The highlights of the microwave-related research at NCU include the activities in the Center for Space and Remote Sensing Research and the Chung Li VHF antenna farm. The Remote Sensing Research Lab houses several strong research activities with an annual combined funding of NT\$143 million. Figure 7 shows the Datron 13 meter antenna at the Satellite Remote Sensing Lab, one component laboratory in the overall center. Figure 8 shows the VHF antenna farm for middle atmosphere and ionosphere research at NCU. It basically consists of a large number of antennas, each consisting of a 3 Yagi antenna array operating at 52 MHz.

Besides extensive state-of-the-art activities in the areas of remote sensing, satellite communication, and atmospheric sounding, colleagues at NCU presented results of some research activities in the area of propagation modeling and measurements. NCU houses unique national program on EduCities. This is a virtual city that educates citizens and students about the Internet. A web site access to information about this concept is <http://www.EduCities.edu.tw>.



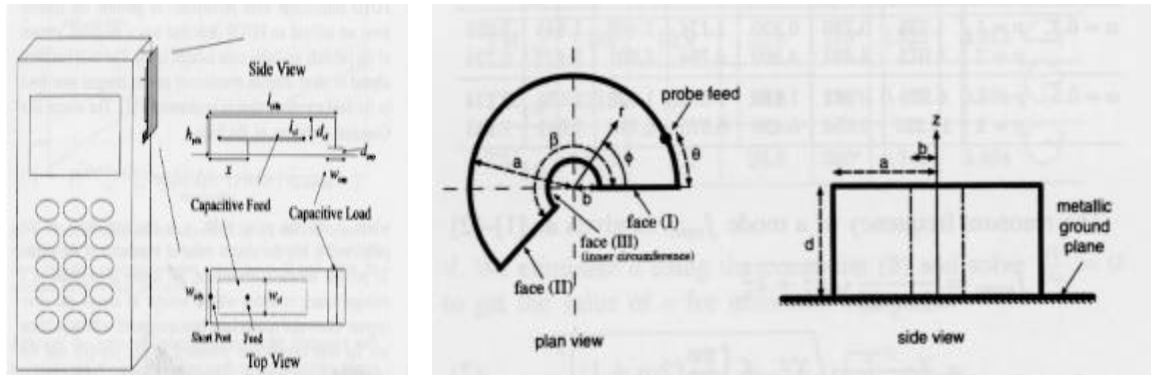
Fig. 7. Datron 13 meter antenna at the Satellite Remote Sensing Laboratory at NCU.



Fig. 8. The Chung-Li VHF Antenna Farm at NCU.

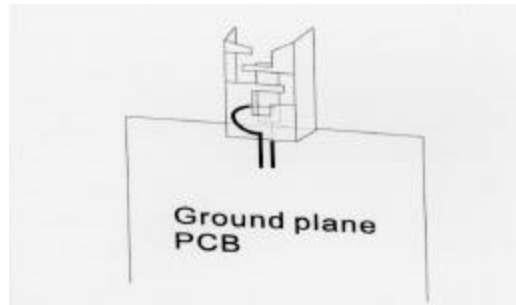
Observations from Visits in Hong Kong

In Hong Kong, microwave research was mentioned at both the University of Hong Kong and the Hong Kong University of Science and Technology. At the University of Hong Kong, strong telecommunication activities were reported in the telecommunication and electromagnetics (EM) laboratory. Facilities include state-of-the-art HP network analyzers, HP spectrum analyzers, synthesized signal generators, and a comprehensive suite of software for microwave and RF circuit design. At the Hong Kong University of Science and Technology, microwave research was focused on antenna development for handsets and mobile receivers. Figure 9 shows some examples of these designs including a capacitively loaded planar inverted F antenna (PIFA) that resulted in a size reduction of almost half (Figure 9a), the compact circular sector and annular sector Dielectric Resonator Antenna (DRA) that resulted in a 75% volume reduction (Figure 9b), and a diversity antenna that merges monopole and slot antenna designs (Figure 9c). In Figure 9c, it may be noted that meandering was implemented to further reduce the size of the slot antenna.



(a) The PIFA antenna.

(b) The circular sector dielectric resonator antenna.



(c) The combined monopole and meandered slot antenna.

Fig. 9. Antenna designs for handsets and mobile wireless communication at HKSTU.

SUMMARY OF FINDINGS AND CONCLUDING REMARKS

The team generally observed strong R&D activities in Taiwan and growing research efforts in Hong Kong. Much of the ongoing research in the microwave area, however, was focused on available technologies. In Taiwan, state-of-the-art laboratory facilities were available at NTU and an internationally recognized research program in the area of remote sensing is housed at NCU. There is a clear commitment on the part of the government to continue and enhance its support for telecommunication research while encouraging these universities to work with and maintain their strong ties with industry. The research and educational activities at NCTU were also very impressive and the propagation sounding lab was state of the art.

In Hong Kong, on the other hand, efforts are still focused on nurturing the business environment, but some efforts are being initiated to strengthen university research and Hong Kong's innovative participation in information technologies. Microwave research at both the University of Hong Kong and Hong Kong Science and Technology University is limited in scope, but it is expected to continue growing as the government in general and the Innovation and Technology Commission in particular continue to support research and provide funding at these universities.

As for mainland China, and based on the limited available information presented in the workshops, it may be concluded that research is focused (90%) on short-term impact, addressing industrial and manufacturing needs, and on meeting the phenomenally growing telecommunication market in China.

When compared with the observed R&D trends in Europe and Japan, it may be observed in the China visits that less emphasis was placed on system-type issues, and the research in China programs is much smaller and more focused on niches rather than on a broader vision of next-generation telecom systems.