CHAPTER 5

SIGNAL PROCESSING

Jack H. Winters

INTRODUCTION

Worldwide, including the U.S., there is significant research and development activity on signal processing for communication systems. This is also true in Hong Kong, Taiwan, and mainland China.

In this chapter, signal processing technology in Hong Kong, Taiwan, and mainland China are discussed. The main areas of signal processing research, which include telecommunications, optoeletronics, and biotechnology are described first, followed by a description of the research being done at universities and in industry and the issues addressed by government agencies based on the panel's site visits. Finally, the panel's conclusions in this area are presented.

AREAS OF SIGNAL PROCESSING RESEARCH

There are three main areas of research in signal processing which the panel saw on the site visits. First is telecommunications. This was by far the area that is receiving the most emphasis. The telecommunications area can be broken into three subareas: wireless, wired, and applications. The wireless area includes research on third generation cellular systems, wireless local area networks, such as 802.11b and 802.11a, Bluetooth, and fixed wireless systems. Figure 1 shows these areas as defined by their data rate versus range from the base station and mobile speed. Note that Bluetooth operates in the ISM band at 2.4 GHz, providing data rates below 1 Mbps over short distances of a few meters. Wireless Local Area Networks (WLANs) consist mainly of 802.11b and 802.11a. 802.11b operates in the 2.4 GHz ISM band, using spread spectrum to provide data rates of 1, 2, 5.5, and 11 Mbps over distances up to a few hundred meters, while 802.11a uses Orthogonal Frequency Division Multiplexing (OFDM) to provide data rates from 6 to 54 Mbps over a few hundred meters. Third generation (3G) cellular systems use Wideband Code Division Multiple Access (WCDMA) to provide data rates up to 2 Mbps indoors, and up to 384 kbps outdoors, with ranges of tens of miles. As noted in the figure, the range œrresponds roughly to the mobile speed, with 3G providing access to users at vehicular speeds, while WLANs provide access to slower moving users and Bluetooth only operates at up to pedestrian speeds. Note that only 802.11b is currently commercially available, although the other systems are planned for deployment within the next year.

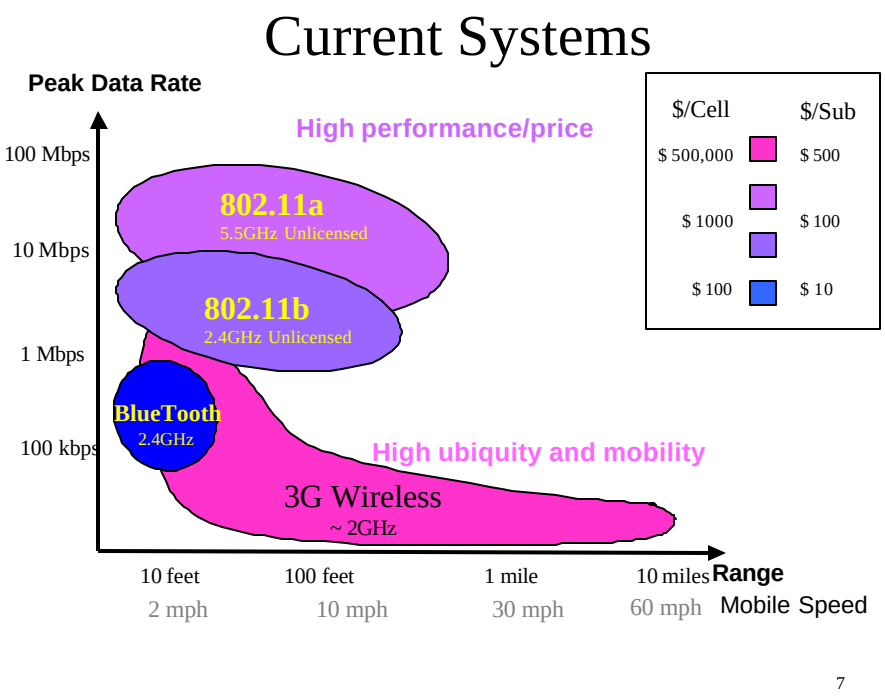


Figure 1

In addition, not shown are fixed wireless systems. These wireless local loop systems consist of many types, but one prominent standard is 802.16. Since this standard uses OFDM, there is significant overlap with 802.11a, with both standards offering the possibility for outdoor access at high data rates.

Also, in the area of telecommunications, there is significant work in wired systems, in particular, Digital Subscriber Line (DSL). This technology uses OFDM to provide high-speed internet access over telephone lines.

Finally, in the area of telecommunications, there is significant work on applications for telecommunications. This is seen as critical for high-speed data as no one is sure what the "killer" application will be. Specifically, without such applications, it is not clear what will be the primary motivation and selling point for high speed wireless, or wired, systems.

Optoelectronics was another key area of signal processing research. Although the panel did not see as much research in this area as in telecommunications, there was still a significant amount of research in this area with emphasis on Dense Wavelength Division Multiplexing (DWDM) for providing very high data rates over fiber.

Lastly, there was research in biotechnology, the interface of man and machine. Although this was by far the area of the least research that panel members saw, it was considered by many universities and companies to be critical to practical usage of communication systems in the future and was therefore seen as having increasing importance.

UNIVERSITY RESEARCH

The panel's overall assessment of research on signal processing at universities in Hong Kong, Taiwan, and mainland China was that there is state-of-the art research covering all major aspects. However, because of the

size of the total research program in Hong Kong and Taiwan (due to the limited number of researchers) there is only limited coverage of these areas. Furthermore, in mainland China, although the research program size is much larger, because of the lack of experienced researchers, particularly professors, the total research effort is still limited.

Areas of research that panel members saw reflected those seen during the previous study of the US, Japan, and Europe. This included research on smart antennas, OFDM, WCDMA, equalization, frequency reuse, power control, dynamic channel assignment, source coding, interoperability of mobile and fixed networks, as well as optical research on Sonet, DWDM, Asynchronous Transfer Mode (ATM), and switching. The two main areas of research in China were smart antennas and OFDM. These two key technologies for future wireless systems are briefly described below.

There are two basic types of smart antennas. As shown in Figure 2, the first type is the phased array or multibeam antenna, where there are a number of beams with one beam turned on towards the desired signal or a single beam which is steered toward the desired signal. The other type is the adaptive antenna array as shown in Figure 3, which is an array of multiple antenna elements, with the received signals weighted and combined to maximize the desired signal to interference plus noise power ratio. This essentially puts a main beam in the direction of the desired signal and nulls in the direction of the interferers. Now the definition that is used for smart antennas is a phased or adaptive array which adjusts to the environment. That is, for the adaptive array, the beam pattern changes as the desired user and interference move, and for the phased array, the beam is steered or different beams are selected as the desired user moves. Both phased and adaptive arrays provide increased power/range/coverage by providing higher gain for the desired signal. Phased arrays use narrow pencil beams, particularly with a large number of antenna elements at higher frequencies, to provide higher gain (power) in the direction of the desired signal. Adaptive arrays place a main beam in the direction of the desired signal for an M-fold power gain with M antenna elements. In terms of interference suppression, phased arrays reduce the probability of interference with the narrower beam, and adaptive arrays adjust the beam pattern to suppress interference, nulling up to M-1 interferers with M antennas. For multipath mitigation, smart antennas can provide diversity, of which there are three basic types: spatial, polarization, and angle (or pattern) diversity. Smart antennas can also be used to provide a multiple-input-multiple-output (MIMO) capacity increase. In particular, since with M receive antennas, up to M-1 interfering signals can be suppressed, the M-1 interfering signals can be other desired signals from a user. Thus, with a user transmitting M different signals out of M antennas, an M-fold increase in capacity can be obtained, most importantly, with no increase in total transmit power.

Another key technology is OFDM. With OFDM, a given bandwidth is divided among overlapping subcarriers. Each carrier has a bandwidth such that the channel is reasonably flat over that bandwidth, thus avoiding the need for equalization. As noted above, OFDM is used in DSL, fixed wireless, 802.11a, and is being considered for fourth generation cellular systems.

As noted above, the universities in Hong Kong and Taiwan cover most of the key areas of telecommunication research, although a limited basis. Figure 4 shows some of the areas of research at one university visited by the panel, National Tsing Hua University. Note the wide range of topics being covered. Similarly, Dr. Ping Zhang, from the Wireless Technology Innovation Laboratory at the Beijing University of Posts and Telecommunications, presented a long list of research areas, including: multiuser detection, smart antennas, OFDM, radio research management, channel coding and decoding, space-time coding, advanced data transmission, mobile IP, wireless multimedia service, systems hardware, and protocols and software.

Figure 2

Phased Array

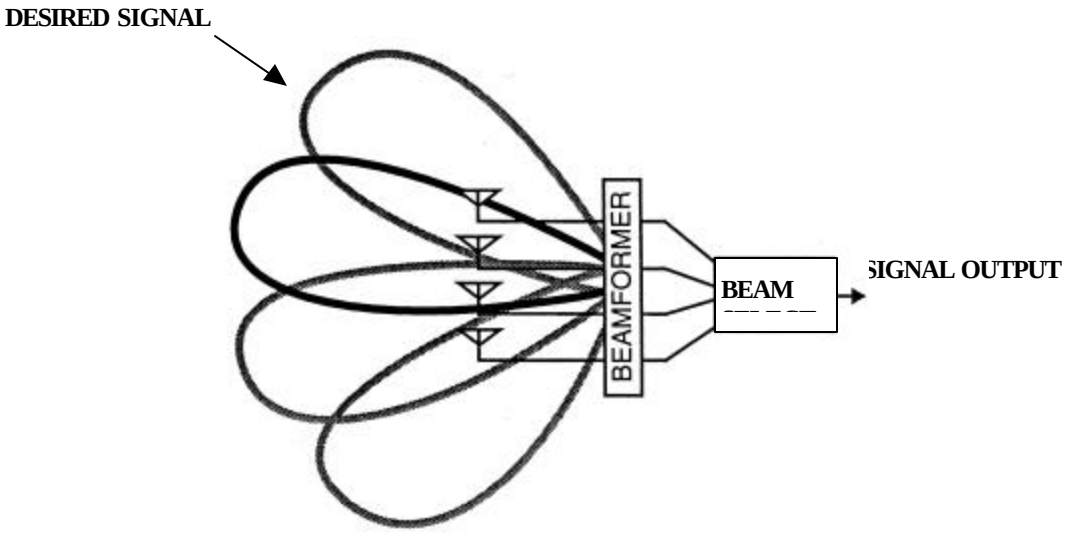
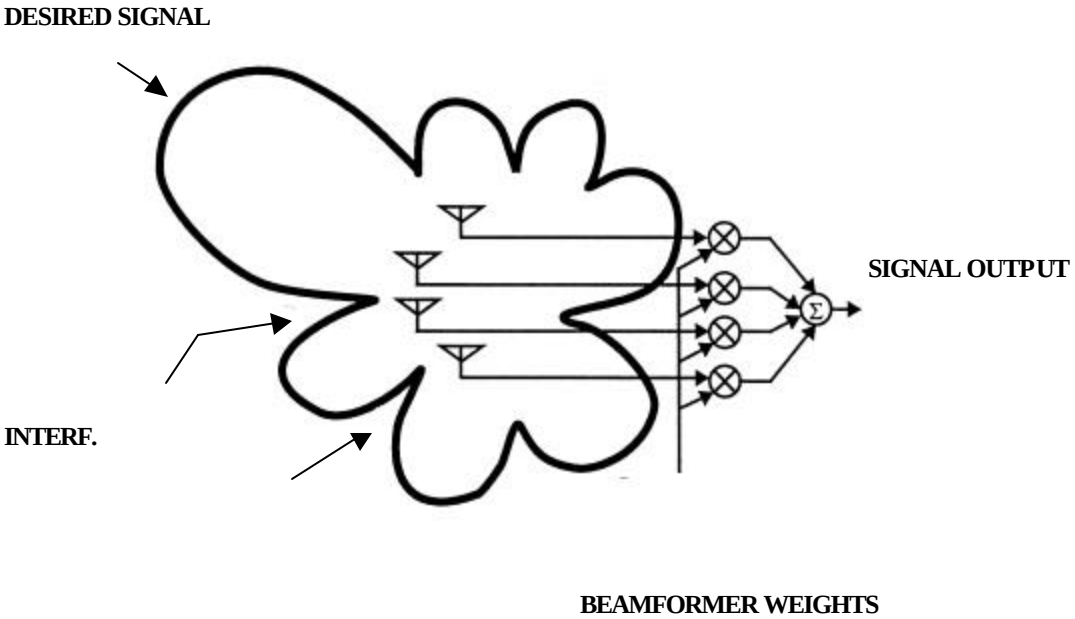


Figure 3

Adaptive Array



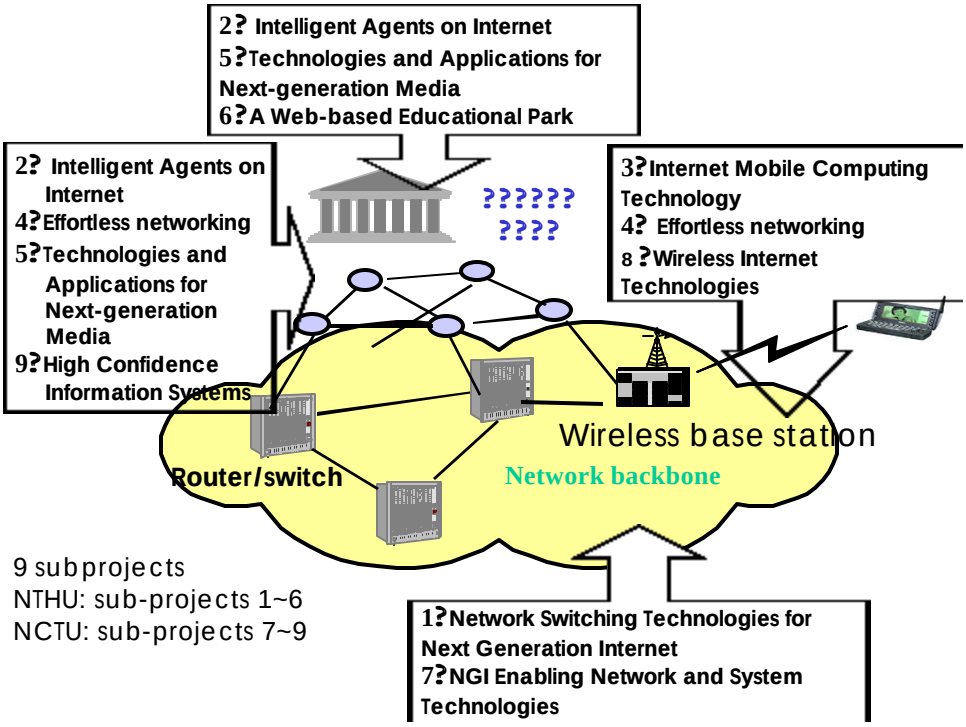


Figure 4

INDUSTRIAL RESEARCH

The panel's overall assessment of industrial research was that most companies do only limited research. This research is primarily based on ways to immediately increase revenue and profits. For example, Chinghua Telecom Labs devotes only 10% of their effort to long-term research. Furthermore, they believe that there is no need for more wireless capacity - they place most of their emphasis on the wired network, in particular, providing higher data rates and capacity for their wired users. This emphasis mainly stems from the current lack of viable applications for high-speed wireless access. Without such applications, the business value for such access is in doubt, and therefore they do not do research on that. Also, at Z-Com, a strong emphasis is on cost. They note that no company is making money on 802.11 data service. Therefore, rather than doing research on smart antennas for performance improvement, they are actually studying the reduction of the number of antennas in their 802.11b terminal card from two to one. They do have a directional antenna (phased array above), however, for 802.11b.

GOVERNMENT AGENCY ISSUES

The panel's overall assessment on the role of the government in Hong Kong, Taiwan, and mainland China is that research is much more driven by the government there than in the US. For example, in Taiwan, the government places a strong emphasis on 3G research in order to catch up for their lack of a significant impact on second generation cellular systems. This emphasis is done by the government because, given the limited size of Taiwan's industries, they believe that they need to focus on one area in order to have an impact. However, placing most of their emphasis in one area has significant risks. In particular, 3G has been

suffering significant setbacks, and it is not clear that it will become popular and profitable, e.g., WLAN technology could take most of the market share. In that case, Taiwan's industry would be severely impacted. The Taiwanese government also wants the industries to move up the chain to systems research, including an emphasis on interaction of signal processing techniques, as was seen in the previous study in the US, Japan, and Europe. However, the panel saw little of this type of research at universities, and none in industries, in any of the countries. This may be hard for them to do, though, because of the limited size of the overall research effort, which makes it difficult to emphasize all areas enough to do overall interaction and system research.

In Hong Kong, the government agency OFTA placed most of their interest on base station antenna esthetics, and health issues from handset radiation into the head. Both of these issues may be helped by smart antennas. An interesting issue in Hong Kong was that the government stated that they would not regulate services provided by WLANs. Although they require licenses for standard providers of cable TV, cellular phones, and local phone service, if these services are provided by WLANs in the ISM band (rather than on a cable, in a licensed band, or via twisted pair, respectively) no license is required. Thus, the regulatory environment is generally more promising in Hong Kong than in the US.

In mainland China, the government determines the general direction and goals of most university and industrial research. For example, for 3G, CDMA2000 was specified and Time Division Synchronous CDMA (TD-SCDMA) is being promoted by the government. The general statement was that, since China may become the world's largest cellular market, they ought to be able to determine the technology to be used. As with Taiwan, picking the wrong technology could be a major problem, but this would be mitigated somewhat by the huge market potential in China.

CONCLUDING REMARKS

In previous visits in Europe and Japan and interactions with US companies, it was seen that their main future research interest was on the vertical integration and interdisciplinary approach to signal processing research. However, the panel did not see this during the visits in Hong Kong, Taiwan, and mainland China. State-of-the-art research in signal processing covering all topics was observed, with the major emphasis on applications. This was particularly true for industrial research, where the main effort was on market and cost-driven research. The regulatory environment appeared to be better than in the US, but the government had a much stronger influence on research, placing emphasis on only a few areas. If these areas are the correct areas, then the signal processing research could have a major worldwide impact - but substantial problems would develop if incorrect.