CHAPTER 8

Bits in the Air

Old Metaphors, New Technologies, and Free Speech

Censoring the President

On July 17, 2006, U.S. President George Bush and British Prime Minister Tony Blair were chatting at the G-8 summit in St. Petersburg, Russia. The event was a photo opportunity, but the two leaders did not realize that a microphone was on. They were discussing what the UN might do to quell the conflict between Israel and militant forces in Lebanon. "See the irony is," said Bush, "what they need to do is get Syria to get Hezbollah to stop doing this shit and it's over."

The cable network CNN carried the clip in full and posted it on the Web, but most broadcast stations bleeped out the expletive. They were aware of the fines, as much as $325,000, that the Federal Communications Commission might impose for airing the word "shit."

The FCC had long regulated speech over the public airways, but had raised its decency standards after the 2002 "Golden Globes" awards presentation. Singer Bono had won the "Best Original Song" award. In his acceptance speech, broadcast live on NBC, he said, "This is really, really, fucking brilliant." The FCC ruled that this remark was "patently offensive under contemporary community standards for the broadcast medium." It promised to fine and even pull the licenses of stations broadcasting such remarks.

In 2006, the Commission extended the principle from the F-word to the S-word. Nicole Richie, referring to a reality TV show on which she had done some farm work, said to Paris Hilton, "Why do they even call it *The Simple Life*? Have you ever tried to get cow shit out of a Prada purse? It's not so fucking simple." The FCC's ruling on Richie's use of the excrement metaphor implied that Bush's use would be "presumptively profane" in the eyes of the FCC.

A federal court reversed the FCC's policy against such "fleeting" expletives—an expansion of indecency policies that had been in place for decades. Congress quickly introduced legislation to restore the FCC's new and strict standard, and the whole matter was to be argued before the U.S. Supreme Court in the spring of 2008. The FCC had adopted its new standards after complaints about broadcast indecency rose from fewer than 50 to about 1.4 million in the period from 2000 to 2004. Congress may have thought that the new speech code reflected a public mandate.

Under the First Amendment, the government is generally not in the speech-restricting business. It can't force its editorial judgments on newspapers, even to increase the range of information available to readers. The Supreme Court struck down as unconstitutional a Florida law assuring political candidates a simple "right to reply" to newspaper attacks on them.

Nonetheless, in 2006, an agency of the federal government was trying to keep words off television, using rules that "presumptively" covered even a candid conversation about war and peace between leaders of the free world. Dozens of newspapers printed Bush's remark in full, and anyone with an Internet connection could hear the audio. In spite of the spike in indecency complaints to the FCC, Americans are generally opposed to having the government nanny their television shows.

How Broadcasting Became Regulated

The FCC gained its authority over what is said on radio and TV broadcasts when there were fewer ways to distribute information. The public airways were scarce, went the theory, and the government had to make sure they were used in the public interest. As radio and television became universally accessible, a second rationale emerged for government regulation of broadcast speech. Because the broadcast media have "a uniquely pervasive presence in the lives of all Americans," as the Supreme Court put it in 1978, the government had a special interest in protecting a defenseless public from objectionable radio and television content.

The explosion in communications technologies has confused both rationales. In the digital era, there are far more ways for bits to reach the consumer, so broadcast radio and television are hardly unique in their pervasiveness.

With minimal technology, anyone can sit at home or in Starbucks and choose from among billions of web pages and tens of millions of blogs. Shock jock Howard Stern left broadcast radio for satellite radio, where the FCC has no authority to regulate what he says. More than 90% of American television viewers get their TV signal through similarly unregulated cable or satellite, not through broadcasts from rooftop antennas. RSS feeds supply up-to-date information to millions of on-the-go cell phone users. Radio stations and television channels are today neither scarce nor uniquely pervasive.

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For the government to protect children from all offensive information arriving through any communication medium, its authority would have to be expanded greatly and updated continuously. Indeed, federal legislation has been introduced to do exactly that—to extend FCC indecency regulations for broadcast media to satellite and cable television as well.

The explosion in communications raises another possibility, however. If almost anyone can now send information that many people can receive, perhaps the government's interest in restricting transmissions should be less than what it once was, not greater. In the absence of scarcity, perhaps the government should have no more authority over what gets said on radio and TV than it does over what gets printed in newspapers. In that case, rather than expanding the FCC's censorship authority, Congress should eliminate it entirely, just as the Supreme Court ended Florida's regulation of newspaper content.

Parties who already have spots on the radio dial and the TV channel lineup respond that the spectrum—the public airwaves—should remain a limited resource, requiring government protection. No one is making any more radio spectrum, goes the theory, and it needs to be used in the public interest.

But look around you. There are still only a few stations on the AM and FM radio dials. But thousands, maybe tens of thousands, of radio communications are passing through the air around you. Most Americans walk around with two-way radios in their pockets—devices we call cell phones—and most of the nation's teenagers seem to be talking on them simultaneously. Radios and television sets could be much, much smarter than they now are and could make better use of the airwaves, just as cell phones do.

Engineering developments have vitiated the government's override of the First Amendment on radio and television. The Constitution demands, under these changed circumstances, that the government stop its verbal policing.

Surviving on Wireless

A dramatic example of the pervasiveness of wireless networks, in spite of the limits on spectrum where they are allowed to operate, was provided in the aftermath of the destruction of the World Trade Center on September 11, 2001. Lower Manhattan communicated for several days largely on the strength of wireless. Something similar happened after the December 2006 earthquake that severed undersea communications cables in southeast Asia.

As a scientific argument, the claim that the spectrum is necessarily scarce is now very weak. Yet that view is still forcefully advanced by the very industry that is being regulated. The incumbent license holders—existing broadcast stations and networks—have an incentive to protect their "turf" in the spectrum against any risk, real or imagined, that their signals might be corrupted. By deterring technological innovation, incumbents can limit competition and avoid capital investments. These oddly intertwined strands—the government's interest in artificial scarcity to justify speech regulation and the incumbents' interest in artificial scarcity to limit competition and costs—today impair both cultural and technological creativity, to the detriment of society.

To understand the confluent forces that have created the world of today's radio and television censorship, we have to go back to the inventors of the technology.

From Wireless Telegraph to Wireless Chaos

Red, orange, yellow, green, blue—the colors of the rainbow—are all different and yet are all the same. Any child with a crayon box knows that they are all different. They are the same because they are all the result of electromagnetic radiation striking our eyes. The radiation travels in waves that oscillate very quickly. The only physical difference between red and blue is that red waves oscillate around 450,000,000,000,000 times per second, and blue waves about 50% faster.

Because the spectrum of visible light is continuous, an infinity of colors exists between red and blue. Mixing light of different frequencies creates other colors—for example, half blue waves and half red creates a shade of pink known as magenta, which does not appear in the rainbow.

In the 1860s, British physicist James Clerk Maxwell realized that light consists of electromagnetic waves. His equations predicted that there might be waves of other frequencies—waves that people couldn't sense. Indeed, such waves have been passing right through us from the beginning of time. They shower down invisibly from the sun and the stars, and they radiate when lightning strikes. No one suspected they existed until Maxwell's equations said they should. Indeed, there should be a whole spectrum of invisible waves of different frequencies, all traveling at the same great speed as visible light.

In 1887, the radio era began with a demonstration by Henrich Hertz. He bent a wire into a circle, leaving a small gap between the two ends. When he set off a big electric spark a few feet away, a tiny spark jumped the gap of the almost-completely-circular wire. The big spark had set off a shower of unseen electromagnetic waves, which had traveled through space and caused electric current to flow in the other wire. The tiny spark was the current completing the circuit. Hertz had created the first antenna, and had revealed the radio waves that struck it. The unit of frequency is named in his honor: One cycle per second is 1 hertz, or Hz for short. A kHz (kilohertz) is a thousand cycles per second, and a MHz (megahertz) is a million cycles per second. These are the units on the AM and FM radio dials.

Gugliemo Marconi was neither a mathematician nor a scientist. He was an inventive tinkerer. Only 13 years old at the time of Hertz's experiment, Marconi spent the next decade developing, by trial and error, better ways of creating bursts of radio waves, and antennas for detecting them over greater distances.

In 1901, Marconi stood in Newfoundland and received a single Morse code letter transmitted from England. On the strength of this success, the Marconi Wireless Telegraph Company was soon enabling ships to communicate with each other and with the shore. When the *Titanic* left on its fateful voyage in 1912, it was equipped with Marconi equipment. The main job of the ship's radio operators was to relay personal messages to and from passengers, but they also received at least 20 warnings from other ships about the icebergs that lay ahead.

The words "Wireless Telegraph" in the name of Marconi's company suggest the greatest limitation of early radio. The technology was conceived as a device for point-to-point communication. Radio solved the worst problem of telegraphy. No calamity, sabotage, or war could stop wireless transmissions by severing cables. But there was a compensating disadvantage: Anyone could listen in. The enormous power of broadcasting to reach thousands of people at once was at first seen as a liability. Who would pay to send a message to another person when anyone could hear it?

As wireless telegraphy became popular, another problem emerged—one that has shaped the development of radio and television ever since. If several people were transmitting simultaneously in the same geographic area, their signals couldn't be kept apart. The *Titanic* disaster demonstrated the confusion that could result. The morning after the ship hit the iceberg, American newspapers reported excitedly that all passengers had been saved and the ship was being towed to shore. The mistake resulted from a radio operator's garbled merger of two unrelated segments of Morse code. One ship inquired if "all Titanic passengers safe?" A completely different ship reported that it was "300 miles west of the Titanic and towing an oil tank to Halifax." All the ships had radios and radio operators. But there were no rules or conventions about whether, how, or when to use them.

Listeners to Marconi's early transmitters were easily confused because they had no way to "tune in" a particular communication. For all of Marconi's genius in extending the range of transmission, he was using essentially Hertz's method for generating radio waves: big sparks. The sparks splattered electromagnetic energy across the radio spectrum. The energy could be stopped and started to turn it into dots and dashes, but there was nothing else to control. One radio operator's noise was like any other's. When several transmitted simultaneously, chaos resulted.

The many colors of visible light look white if all blended together. A color filter lets through some frequencies of visible light but not others. If you look at the world through a red filter, everything is a lighter or darker shade of red, because only the red light comes through. What radio needed was something similar for the radio spectrum: a way to produce radio waves of a single frequency, or at least a narrow range of frequencies, and a receiver that could let through those frequencies and screen out the rest. Indeed, that technology already existed.

In 1907, Lee De Forest patented a key technology for the De Forest Radio Telephone Company—dedicated to sending voice and even music over the radio waves. When he broadcast Enrico Caruso from the Metropolitan Opera House on January 13, 1910, the singing reached ships at sea. Amateurs huddled over receivers in New York and New Jersey. The effect was sensational. Hundreds of amateur broadcasters sprang into action over the next few years, eagerly saying whatever they wanted, and playing whatever music they could, to anyone who happened to be listening.

With no clear understanding about what frequencies to use, radio communication was a hit-or-miss affair.

But with no clear understanding about what frequencies to use, radio communication was a hit-or-miss affair. Even what the *New York Times* described as the "homeless song waves" of the Caruso broadcast clashed with another station that, "despite all entreaties," insisted on broadcasting at the identical 350kHz frequency. Some people could "catch the ecstasy" of Caruso's voice, but others got only some annoying Morse code: "I took a beer just now."

Radio Waves in Their Channels

The emerging radio industry could not grow under such conditions. Commercial interests complemented the concerns of the U.S. Navy about amateur interference with its ship communications. The *Titanic* disaster, although it owed little to the failures of radio, catalyzed government action. On May 12, 1912, William Alden Smith called for radio regulation on the floor of the U.S. Senate. "When the world weeps together over a common loss...," proclaimed the Senator, "why should not the nations clear the sea of its conflicting idioms and wisely regulate this new servant of humanity?"

The Radio Act of 1912 limited broadcasting to license holders. Radio licenses were to be "granted by the Secretary of Commerce and Labor upon application therefor." In granting the license, the Secretary would stipulate the frequencies "authorized for use by the station for the prevention of interference and the hours for which the station is licensed for work." The Act reserved for government use the choice frequencies between about 200 and 500kHz, which permitted the clearest communications over long distances. Amateurs were pushed off to "short wave" frequencies above 1500kHz, considered useless for technological reasons. The frequency 1000kHz was reserved for distress calls, and licensed stations were required to listen to it every 15 minutes (the one provision that

High Frequencies

Over the years, technological improvements have made it possible to use higher and higher frequencies. Early TV was broadcast at what were then considered "Very High Frequencies" (VHF) because they were higher than AM radio. Technology improved again, and more stations appeared at "Ultra High Frequencies" (UHF). The highest frequency in commercial use today is 77GHz—77 gigahertz, that is, 77,000MHz. In general, high frequency signals fade with distance more than low signals, and are therefore mainly useful for localized or urban environments. Short waves correspond to high frequencies because all radio waves travel at the same speed, which is the speed of light.

might have helped the *Titanic*, since the radio operators of a nearby ship had gone off-duty and missed the *Titanic's* rescue pleas). The rest of the spectrum the Secretary could assign to commercial radio stations and private businesses. Emphasizing the nature of radio as "wireless telegraphy," the Act made it a crime for anyone hearing a radio message to divulge it to anyone except its intended recipient.

Much has changed since 1912. The uses of radio waves have become more varied, the allocation of spectrum blocks has changed, and the range of usable frequencies has grown. The current spectrum allocation picture has grown into a dense, disorganized quilt, the product of decades of Solomonic FCC judgments (see Figure 8.1). But still, the U.S. government stipulates what parts of the spectrum can be used for what purposes. It prevents users from interfering with each other and with government communications by demanding that they broadcast at limited power and only at their assigned frequencies. As long as there weren't many radio stations, the implied

Source: `www.ntia.doc.gov/osmhome/allochrt.pdf`.

FIGURE 8.1 Frequency allocation of the U.S. radio spectrum. The spectrum from 3kHz to 300GHz is laid out from left to right and top to bottom, with the scale 10 times denser in each successive row. For example, the large block in the second row is the AM radio dial, about 1MHz wide. The same amount of spectrum would be about .00002 of an inch wide in the bottom row.

promise in the Act of 1912 that licenses would be granted "upon application therefor" caused no problems. With the gossip of the pesky amateurs pushed into remote radio territory, there was plenty of spectrum for commercial, military, and safety use.

Within a decade, that picture had changed dramatically. On November 2, 1920, a Detroit station broadcast the election of Warren Harding as President of the United States, relaying to its tiny radio audience the returns it was receiving by telegraph. Radio was no longer just point-to-point communication. A year later, a New York station broadcast the World Series between the Giants and the Yankees, pitch by pitch. Sports broadcasting was born with a broadcaster drearily repeating the ball and strike information telephoned by a newspaper reporter at the ballpark.

Public understanding of the possibilities grew rapidly. The first five radio stations were licensed for broadcasting in 1921. Within a year, there were 670. The number of radio receivers jumped in a year from less than 50,000 to more than 600,000, perhaps a million. Stations using the same frequency in the same city divided up the hours of the day. As radio broadcasting became a profitable business, the growth could not go on forever.

On November 12, 1921, the New York City broadcast license of Intercity Radio Co. expired. Herbert Hoover, then the Secretary of Commerce, refused to renew it, on the grounds that there was no frequency on which Intercity could broadcast in the city's airspace without interfering with government or other private stations. Intercity sued Hoover to have its license restored, and won. Hoover, said the court, could choose the frequency, but he had no discretion to deny the license. As the congressional committee proposing the 1912 Radio Act had put it, the licensing system was "substantially the same as that in use for the documenting upward of 25,000 merchant vessels." The implied metaphor was that Hoover should keep track of the stations like ships in the ocean. He could tell them what shipping lanes to use, but he couldn't keep them out of the water.

The radio industry begged for order. Hoover convened a National Radio Conference in 1922 in an attempt to achieve consensus on new regulations before chaos set in. The spectrum was "a great national asset," he said, and "it becomes of primary public interest to say who is to do the broadcasting, under what circumstances, and with what type of material." "[T]he large mass of subscribers need protection as to the noises which fill their instruments," and the airwaves need "a policeman" to detect "hogs that are endangering the traffic."

Hoover divided the spectrum from 550kHz to 1350kHz in 10kHz bands—called "channels," consistent with the nautical metaphor—to squeeze in more stations. Empty "guard bands" were left on each side of allocated bands because broadcast signals inevitably spread out, reducing the amount of usable spectrum. Persuasion and voluntary compliance helped Hoover limit interference. As stations became established, they found it advantageous to comply with Hoover's prescriptions. Start-ups had a harder time breaking in. Hoover convinced representatives of a religious group that to warn of the coming apocalypse, they should buy time on existing stations rather than build one of their own. After all, their money would go farther that way—in six months, after the world had ended, they would have no further use for a transmitter. Hoover's effectiveness made Congress complacent—the system was working well enough without laws.

But as the slicing got finer, the troubles got worse. WLW and WMH in Cincinnati broadcast on the same frequency in 1924 until Hoover brokered a deal for three stations to share two frequencies in rotating time slots. Finally, the system broke down. In 1925, Zenith Radio Corporation was granted a license to use 930kHz in Chicago, but only on Thursday nights, only from 10 p.m. to midnight, and only if a Denver station didn't wish to broadcast then. Without permission, Zenith started broadcasting at 910kHz, a frequency that was more open because it had been ceded by treaty to Canada. Hoover fined Zenith; Zenith challenged Hoover's authority to regulate frequencies, and won in court. The Secretary then got even worse news from the U.S. Attorney General: The 1912 Act, drafted before broadcasting was even a concept, was so ambiguous that it probably gave Hoover no authority to regulate anything about broadcast radio—frequency, power, or time of day.

Hoover threw up his hands. Anyone could start a station and choose a frequency—there were 600 applications pending—but in doing so, they were "proceeding entirely at their own risk." The result was the "chaos in the air" that Hoover had predicted. It was worse than before the 1912 Act because so many more transmitters existed and they were so much more powerful. Stations popped up, jumped all over the frequency spectrum in search of open air, and turned up their transmission power to the maximum to drown out competing signals. Radio became virtually useless, especially in cities. Congress finally was forced to act.

The Spectrum Nationalized

The premises of the Radio Act of 1927 are still in force. The spectrum has been treated as a scarce national resource ever since, managed by the government.

The purpose of the Act was *to maintain the control of the United States over all the channels of ... radio transmission; and to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority....* The public could use the spectrum, under conditions stipulated by the government, but could not own it. A new authority, the Federal Radio Commission (FRC), made licensing decisions. The public had a qualified expectation that license requests would be granted: *The licensing authority, if public convenience, interest, or necessity will be served thereby, ... shall grant to any applicant therefor a station license....* The Act recognized that demand for licenses could exceed the supply of spectrum. In case of competition among applicants, *the licensing authority shall make such a distribution of licenses, bands of frequency..., periods of time for operation, and of power among the different States and communities as to give fair, efficient, and equitable radio service to each....*

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THE "RADIO COMMISSION" GROWS

In 1934, the FRC's name was changed to the Federal Communications Commission—the FCC—when telephone and telegraph regulation came under the Commission's oversight. When a separate chunk of radio spectrum was allocated for television, the FCC assumed authority over video broadcasts as well.

The language about "public convenience, interest, or necessity" echoes Hoover's 1922 speech about a "national asset" and the "public interest." It is also no accident that this law was drafted as the Teapot Dome Scandal was cresting. Oil reserves on federal land in Wyoming had been leased to Sinclair Oil in 1923 with the assistance of bribes paid to the Secretary of the Interior. It took several years for Congressional investigations and federal court cases to expose the wrongdoing; the Secretary was eventually imprisoned. By early 1927, the fair use of national resources in the public interest was a major concern in the United States.

With the passage of the Act of 1927, the radio spectrum became federal land. International treaties followed, to limit interference near national borders. But within the U.S., just as Hoover had asked five years earlier, the federal government took control over who would be allowed to broadcast, which radio waves they could use—and even what they could say.

Goat Glands and the First Amendment

The Radio Act of 1927 stipulated that the FRC could not abridge free speech over the radio. *Nothing in this Act shall be understood or construed to give the licensing authority the power of censorship..., and no regulation or condition ... shall interfere with the right of free speech by means of radio communications.* Inevitably, a case would arise exposing the implicit conflict: On the one hand, the Commission had to use a public interest standard when granting and renewing licenses. On the other, it had to avoid censorship. The pivotal case was over the license for KFKB radio, the station of the Kansas goat-gland doctor, John Romulus Brinkley (see Figure 8.2). The wrath brought down on CBS in 2004 for showing a flash of Janet Jackson's breast—and which the networks feared if they broadcast *Saving Private Ryan* on

PREACHES FUNDAMENTALISM PRACTICES GOAT-GLAND SCIENCE

How a Famous Surgeon Combines Old-Time Religion and New-Fangled Operations on a Strange Medico-Gospel Farm

SCIENTIST AND PROTEGE. Dr. John R. Brinkley, Eminent Surgeon and Ardent Fundamentalist, with "Billy," Now 5 Years Old, the First "Goat-Gland Baby."

WIFE AND SWISS KIDS. Mrs. Minnie Brinkley Holding Two Fine Young Specimens of Toggenberg Goats, Used in Her Husband's Delicate Organ-Graftings.

MEET the most unusual scientist - fundamentalist in the whole world, Dr. John R. Brinkley, of Milford, Kan., who saves souls with the word of God and repairs human bodies with glands from lively goats.

A surgeon of distinction, whose services have been recognized here and abroad, the doctor is today a devout and literal believer in the teachings of the Bible. This strain of faith strongly permeates Brinkley Institute, a community centre ("teaching and promoting Bible, health, citizenship, recreation and music") at Milford. But it does not detract from the fact that Dr. Brinkley began his career, in 1911, as the first goat-gland transplanting expert in the United States, some say in the world.

Today, chief surgeon and owner of the Kansas General Research Hospital, at Milford, ten miles from the stone marking the geographical centre of this country, Dr. Brinkley gained scientific distinction during the World War. At the onset of hostilities between America and the central empires, as an A. E. F. veterinary surgeon, he continued to make his daring gland transplantation experiments to renew functional powers that in men and women had been weakened or worn out.

He discovered, among other things, that certain quadrupeds' glands wouldn't do for human beings—those of the bull were "too strenuous," those of apes were too short-lived and too prone to physical decay. Finally, he came to the conclusion that goats, preferably the Toggenberg species of Switzerland, approached the ideal, since they were practically diseaseless and their glands strongly resembled those of *homo sapiens*.

With the war at an end, he found it possible to devote the major part of his time to the importation of the frisky Toggenbergs and the conversion of their glands into human agencies. More than 4,000 individuals of both sexes, many of them prominent people, were treated by him—and successfully.

Brinkley's signal triumphs in this newest and most delicate form of medical science were not received with a unanimous shout of approbation. Old-time surgeons got quite hot under the collar, and he was even charged with practicing under a license obtained by fraud. Dropped from the list of practitioners in Missouri, Connecticut and California, he appealed to the courts, receiving a complete vindication.

Rightfully flushed with his victory on native soil, Dr. Brinkley went abroad for study and research. The Royal University of Pavia, Italy, which had awarded degrees to Napoleon, Michael Angelo and various Italian rulers, licensed him to practice. He was the only American ever accorded such an honor. In London, later, the British Medical Association gave him similar laurels after he had passed its rigid examination.

Back in the States, Brinkley found a storm brewing in his home state, Tennessee. The great Scopes trial was in process of incubation. The returning scientist, himself a Tennessean, saw and sympathized with the mountaineers' efforts to keep their beloved religion untouched by scientific fingers. Perhaps some hidden mental echo of his boyhood in that region awoke within him the latest sparks of devotional fervor. Perhaps the white-hot oratory of the late William Jennings Bryan struck a response in his heart.

Whatever the cause, Brinkley opened his hands to fundamentalism. He converted his spacious grounds at Milford into a glorified camp-meeting ground. At the same time he reserved the hospital for continued gland transplantations. Thus soul-saving and bodily repairing went hand in hand under the keen eye of one of the best scientists and firmest "believers" on the globe.

A first-hand pen picture of this extraordinary man is supplied by a friend of long standing. "Probably," says this individual, "there never was so odd a mixture of talents and tendencies as John. He is a thirty-second degree Mason. In 1923 he erected a broadcasting station at a cost of $50,000 to put his medical lectures on the air and also to establish the Manhattan Agricultural College as 'the first college of the air.' When he first went to Italy, he sold this station at 'a total loss.' Back home, having gotten religion, he repurchased the station to broadcast fundamentalist doctrines and denounce evolutionists and 'other workers of the devil'."

SUNDAY SCHOOL.
Children on the Playground at Milford, Kansas, Where Rigid Fundamentalism Is Taught, Despite the Adjacency of Dr. Brinkley's Gland Hospital Activities.

Mrs. Minnie Brinkley, wife of the religious scientist and press representative of his institute, has embodied in letters to friends in the East the working pattern of the doctor's current philosophy. "You and your evolution theory are all wrong," she wrote to one New York acquaintance of the family. "You can't deny the Supreme Ruler of the universe and get away with it—with us. Remember, we are Tennessee people, but of the mountains, but the same heart, and we are a success in this world. . . . We are afraid to know anyone who blasphemes as you did in your letter. You can't refuse our God and get away with it. We are not the kind of Christians who just pray; we work."

PREACHES GOSPEL.
Dr. Charles Draper, Pastor of the Brinkley Institute, Who Doesn't Believe in Scientific Evolution.

Further insight into the workings of Dr. Brinkley's system of religious training, as exemplified in his choice of an assistant, is afforded in another of his wife's communications: "Dr. Charles Draper, of Kansas City, Fort Worth, St. Louis and Chicago, where he had done big work in representing his Almighty God, in a positive defense of the truth as seen by the miracles of Jesus Christ, was told of this project at Milford.

"Dr. Brinkley hired Dr. Draper at Dr. Draper's own price and paid for a picture machine and reels and built a picture house and bandstand for the local band and built benches in the park and a platform, and put a piano on it. Every Sunday and Wednesday nights moral and religious pictures are shown to remind people of the Greatest Man ever known."

Tennis and basketball courts, children's playgrounds, a merry-go-round and other features are a part of Dr. Draper's vision of what should be at Milford. To build up this project subscriptions are being volunteered by neighbors. Some farmers donate about $5 apiece. Dressmakers give the price they charge for one gown.

Such is the remarkable labor which Dr. Brinkley has set himself, as an international scientist, and one who, later, "following the gleam," has determined to stick by his forefathers' creeds—glands or no glands.

New York Evening Journal, September 11, 1926. Microfilm courtesy of the Library of Congress.

FIGURE 8.2 A planted newspaper article about "Dr." Brinkley's goat-gland clinic. The doctor himself is shown at the left, holding the first baby—named "Billy," of course—conceived after a goat-gland transplant.

Veterans' Day or President Bush muttering to Tony Blair—descends from the FCC's action against this classic American charlatan.

Brinkley, born in 1885, became a "doctor" licensed to practice in Kansas by buying a degree from the Eclectic Medical University in Kansas City. He worked briefly as a medic for Swift & Co., the meatpackers. In 1917, he set up his medical practice in Milford, a tiny town about 70 miles west of Topeka. One day, a man came for advice about his failing virility, describing himself as a "flat tire." Drawing on his memory of goat behavior from his days at the slaughterhouse, Brinkley said, "You wouldn't have any trouble if you had a pair of those buck glands in you." "Well, why don't you put 'em in?" the patient asked. Brinkley did the transplant in a back room, and a business was born. Soon he was performing 50 transplants a month, at $750 per surgery. In time, he discovered that promising sexual performance was even more lucrative than promising fertility.

As a young man, Brinkley had worked at a telegraph office, so he knew the promise of communication technology. In 1923, he opened Kansas's first radio station, KFKB—"Kansas First, Kansas Best" radio, or sometimes "Kansas Folks Know Best." The station broadcast a mixture of country music, fundamentalist preaching, and medical advice from Dr. Brinkley himself. Listeners sent in their complaints, and the advice was almost always to buy some of Dr. Brinkley's mail-order patent medicines. "Here's one from Tillie," went a typical segment. "She says she had an operation, had some trouble 10 years ago. I think the operation was unnecessary, and it isn't very good sense to have an ovary removed with the expectation of motherhood resulting therefrom. My advice to you is to use Women's Tonic No. 50, 67, and 61. This combination will do for you what you desire if any combination will, after three months persistent use."

KFKB had a massively powerful transmitter, heard halfway across the Atlantic. In a national poll, it was the most popular station in America—with four times as many votes as the runner-up. Brinkley was receiving 3,000 letters a day and was a sensation throughout the plains states. On a good day, 500 people might show up in Milford. But the American Medical Association—prompted by a competing local radio station—objected to his quackery. The FRC concluded that "public interest, convenience, or necessity" would not be served by renewing the license. Brinkley objected that the cancellation was nothing less than censorship.

An appeals court sided with the FRC in a landmark decision. Censorship, the court explained, was prior restraint, which was not at issue in Brinkley's case. The FRC had "merely exercised its undoubted right to take note of appellant's past conduct." An arguable point—as Albert Gallatin said more than 200 years ago about prior restraint of the press, it was "preposterous to say, that to punish a certain act was not an abridgment of the liberty of doing that act."

The court used the public land metaphor in justifying the FRC's action. "[B]ecause the number of available broadcasting frequencies is limited," wrote the court, "the commission is necessarily called upon to consider the character and quality of the service to be rendered.... Obviously, there is no room in the broadcast band for every business or school of thought."

"Necessarily" and "obviously." It is always wise to scrutinize arguments that proclaim loudly how self-evident they are. Judge Felix Frankfurter, in an opinion on a different case in 1943, restated the principle in a form that has often been quoted. "The plight into which radio fell prior to 1927 was attributable to certain basic facts about radio as a means of communication—its facilities are limited; they are not available to all who may wish to use them; the radio spectrum simply is not large enough to accommodate everybody. There is a fixed natural limitation upon the number of stations that can operate without interfering with one another."

These were facts of the technology of the time. They were true, but they were contingent truths of engineering. They were never universal laws of physics, and are no longer limitations of technology. Because of engineering innovations over the past 20 years, there is no practically significant "natural limitation" on the number of broadcast stations. Arguments from inevitable scarcity can no longer justify U.S. government denials of the use of the airwaves.

The vast regulatory infrastructure, built to rationalize use of the spectrum by much more limited radio technology, has adjusted slowly—as it almost inevitably must: Bureaucracies don't move as quickly as technological innovators. The FCC tries to anticipate resource needs centrally and far in advance. But technology can cause abrupt changes in supply, and market forces can cause abrupt changes in demand. Central planning works no better for the FCC than it did for the Soviet Union.

Moreover, plenty of stakeholders in old technology are happy to see the rules remain unchanged. Like tenants enjoying leases on public land, incumbent radio license holders have no reason to encourage competing uses of the assets they control. The more money that is at stake, the greater the leverage of the profitable ventures. Radio licenses had value almost from the beginning, and as scarcity increased, so did price. By 1925, a Chicago license was sold for $50,000. As advertising expanded and stations bonded into networks, transactions reached seven figures. After the 1927 Act, disputes between stations had to be settled by litigation, trips to Washington, and pressure by friendly Congressional representatives—all more feasible for stations with deep pockets. At first, there were many university stations, but the FRC squeezed them as the value of the airwaves went up. As non-profits, these stations could not hold their ground. Eventually, most educational stations sold out to commercial broadcasters. *De facto*, as one historian put it, "while talking in terms of the public interest, ... the commission actually chose to further the ends of the commercial broadcasters."

The Path to Spectrum Deregulation

When you push a button on your key fob and unlock your car doors, you are a radio broadcaster. The signal from the key fob uses a bit of the spectrum. The key fob signal obeys the same basic physical laws as WBZ's radio broadcasts in Boston, which have been going on continuously since WBZ became the first Eastern commercial station in 1921. But the new radio broadcasts are different in two critical respects. There are hundreds of millions of them going on every day. And while WBZ's broadcast power is 50,000 watts, a key fob's is less than .0002 of a watt.

If the government still had to license every radio transmitter—as Congress authorized in the aftermath of the radio chaos of the 1920s—neither radio key fobs nor any of hundreds of other innovative uses of low-power radio could have come about. The law and the bureaucracy it created would have snuffed this part of the digital explosion.

Another development also lay behind the wireless explosion. Technology had to change so that the available spectrum could be used more efficiently. Digitalization and miniaturization changed the communications world. The story of cell phones and wireless Internet and many conveniences as yet unimagined is a knot of politics, technology, and law. You can't understand the knot without understanding the strands, but in the future, the strands need not remain tied up in the same way as they are today.

From a Few Bullhorns to Millions of Whispers

Thirty years ago, there were no cell phones. A handful of business executives had mobile phones, but the devices were bulky and costly. Miniaturization helped change the mobile phone from the perk of a few corporate bigwigs into the birthright of every American teenager. But the main advance was in *spectrum allocation*—in rethinking the way the radio spectrum was used.

In the era of big, clunky mobile phones, the radio phone company had a big antenna and secured from the FCC the right to use a few frequencies in an urban area. The executive's phone was a little radio station, which broadcast its call. The mobile phone had to be powerful enough to reach the company's antenna, wherever in the city the phone might be located. The number of simultaneous calls was limited to the number of frequencies allocated to the company. The technology was the same as broadcast radio stations used, except that the mobile phone radios were two-way. The scarcity of spectrum, still cited today in limiting the number of broadcast channels, then limited the number of mobile phones. Hoover understood this way back in 1922. "Obviously," he said, "if 10,000,000 telephone subscribers are crying through the air for their mates ... the ether will be filled with frantic chaos, with no communication of any kind possible."

Cellular technology exploits Moore's Law. Phones have become faster, cheaper, and smaller. Because cell phone towers are only a mile or so apart, cell phones need only be powerful enough to send their signals less than a mile. Once received by an antenna, the signal is sent on to the cell phone company by "wireline"—i.e., by copper or fiber optic cables on poles or underground. There need be only enough radio spectrum to handle the calls within the "cell" surrounding a tower, since the same frequencies can be used simultaneously to handle calls in other cells. A lot of fancy dancing has to be done to prevent a call from being dropped as an active phone is carried from cell to cell, but computers, including the little computers inside cell phones, are smart and fast enough to keep up with such rearrangements.

Cell phone technology illustrates an important change in the use of radio spectrum. Most radio communications are now over short distances. They are transmissions between cell phone towers and cell phones. Between wireless routers at Starbucks and the computers of coffee drinkers. Between cordless telephone handsets and their bases. Between highway toll booths and the transponders mounted on commuters' windshields. Between key fobs with buttons and the cars they unlock. Between Wii remotes and Wii game machines. Between iPod transmitters plugged into cars' cigarette lighters and the cars' FM radios.

Even "satellite radio" transmissions often go from a nearby antenna to a customer's receiver, not directly from a satellite orbiting in outer space. In urban areas, so many buildings lie between the receiver and the satellite that the radio companies have installed "repeaters"—antennas connected to each other by wireline. When you listen to XM or Sirius in your car driving around a city, the signal is probably coming to you from an antenna a few blocks away.

The radio spectrum is no longer mainly for long-range signaling. Spectrum policies were set when the major use of radio was for ship-to-shore transmissions, SOS signaling from great distances, and broadcasting over huge geographic areas. As the nation has become wired, most radio

The radio spectrum is no longer mainly for long-range signaling.

signals travel only a few feet or a few hundred feet. Under these changed conditions, the old rules for spectrum management don't make sense.

Can We Just Divide the Property Differently?

Some innovations make better use of the spectrum without changing the fundamental allocation picture shown in Figure 8.1. For example, HD radio squeezes an unrelated low-power digital transmission alongside the analog AM and FM radio channels. ("HD" is a trademark. It doesn't stand for "high definition.") On AM HD radio, the HD transmission uses the guard bands on either side of an AM station for entirely different broadcast content (see Figure 8.3). Most AM radios filter out any signal in the channels adjacent to the one to which it is tuned, so the HD transmission is inaudible on an ordinary radio, even as noise. The HD radio broadcast can be heard only on a special radio designed to pick up and decode the digital transmission.

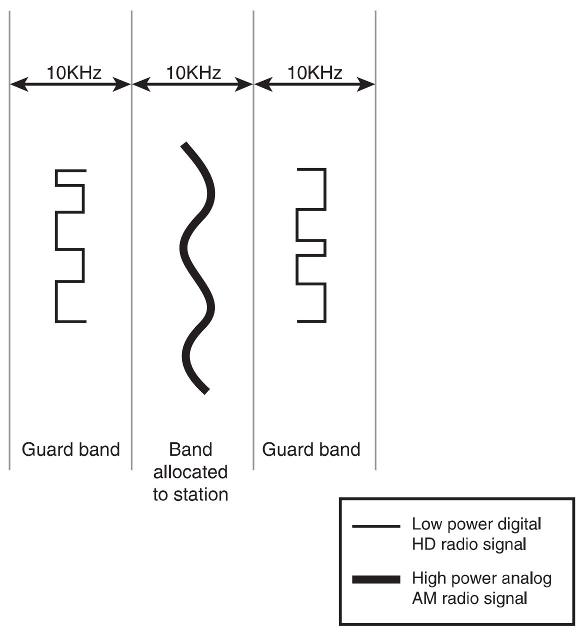


FIGURE 8.3 HD radio uses guard bands to broadcast digital signals at low power. In the AM spectrum, the 10kHz bands on either side of the band allocated to an ordinary analog broadcast station may be used for an entirely independent digital broadcast, limited to low power so that it does not interfere with reception of the analog broadcast.

HD radio is a clever invention, and by opening the spectrum to HD broadcasts, the FCC has been able to squeeze in more broadcast stations—at least for those willing to buy special radios. But it doesn't challenge the fundamental model that has been with us since the 1920s: Split up the spectrum and give a piece to each licensee.

Even parts of the spectrum that are "allocated" to licensees may be drastically underused in practice. A 2002 Federal Communications Committee Report puts it this way: "... the shortage of spectrum is often a*spectrum access problem*. That is, the spectrum resource is available, but its use is compartmented by traditional policies based on traditional technologies." The committee came to this conclusion in part by listening to the air waves in various frequency blocks to test how often nothing at all was being transmitted. Most of the time, even in the dense urban settings of San Diego, Atlanta, and Chicago, important spectrum bands were nearly 100% idle. The public would be better served if others could use the otherwise idle spectrum.

For about ten years, the FCC has experimented with "secondary spectrum marketing." Someone wanting some spectrum for temporary use may be able to lease it from a party who has a right to use it, but is willing to give it up in exchange for a payment. A university radio station, for example, may need the capacity to broadcast at high power only on a few Saturday afternoons to cover major football games. Perhaps such a station could make a deal with a business station that doesn't have a lot of use for its piece of the spectrum when the stock markets are closed. As another example, instead of reserving a band exclusively for emergency broadcasts, it could be made available to others, with the understanding—enforced by codes wired into the transmitters—that the frequency would be yielded on demand for public safety broadcasts.

As the example of eBay has shown, computerized auctions can result in very efficient distribution of goods. The use of particular pieces of the spectrum—at particular times, and in particular geographic areas—can create efficiencies if licensees of under-utilized spectrum bands had an incentive to sell some of their time to other parties.

But secondary markets don't change the basic model—a frequency band belongs to one party at a time. Such auction ideas change the allocation scheme. Rather than having a government agency license spectrum statically to a single party with exclusive rights, several parties can divide it up and make trades. But these schemes retain the fundamental notion that spectrum is like land to be split up among those who want to use it.

Sharing the Spectrum

In his 1943 opinion, Justice Frankfurter used an analogy that unintentionally pointed toward another way of thinking. Spectrum was inevitably scarce, he opined. "Regulation of radio was therefore as vital to its development as traffic control was to the development of the automobile."

Just as the spectrum is said to be, the roadways are a national asset. They are controlled by federal, state, and local governments, which set rules for their use. You can't drive too fast. Your vehicle can't exceed height and weight limits, which may depend on the road.

But everyone shares the roads. There aren't any special highways reserved for government vehicles. Trucking companies can't get licenses to use particular roads and keep out their competitors. Everybody shares the capacity of the roads to carry traffic.

The roads are what is known in law as a "commons" (a notion introduced in Chapter 6). The ocean is also a commons, a shared resource subject to international fishing agreements. In theory at least, the ocean need not be a commons. Fishing boats could have exclusive fishing rights in separate sectors of the ocean's surface. If the regions were large enough, fishermen might be able to earn a good living under these conditions. But such an allocation of the resources of the ocean would be dreadfully inefficient for society as a whole. The oceans better satisfy human needs if they are treated as a commons and fishing boats move with the fish—under agreed limits about the intensity of fishing.

> Yochai Benkler's site, `www.benkler.org`, has several important and readable papers for free download, including the classic "Overcoming Agoraphobia." His book, *The Wealth of Networks* (Yale University Press, 2007), details these and other concepts.

The spectrum can be shared rather than split up into pieces. There is a precedent in electronic communications. The Internet is a digital commons. Everyone's packets get mixed with everyone else's on the fiber optics and satellite links of the Internet backbone. The packets are coded. Which packet belongs to whom is sorted out at the ends. Anything confidential can be encrypted.

Something similar can be done with broadcasts—provided there is a basic rethinking of spectrum management. Two ideas are key: first, that using lots of bandwidth need not cause interference and can greatly increase transmission capacity; and second, that putting computers into radio receivers can greatly improve the utilization of the spectrum.

The Most Beautiful Inventor in the World

Spread spectrum was discovered and forgotten several times and in several countries. Corporations (ITT, Sylvania, and Magnavox), universities (especially MIT), and government laboratories doing classified research all shared in giving birth to this key component of modern telecommunications—and were often unaware of each other's activities.

By far the most remarkable precedent for spread spectrum was a patented invention by Hollywood actress Hedy Lamarr—"the most beautiful woman in the world," in the words of movie mogul Louis Mayer—and George Antheil, an avant-garde composer known as "the bad boy of music."

Lamarr made a scandalous name for herself in Europe by appearing nude in 1933, at the age of 19, in a Czech movie, *Ecstasy*. She became the trophy wife of Fritz Mandl, an Austrian munitions maker whose clients included both Hitler and Mussolini. In 1937, she disguised herself as a maid and escaped Mandl's house, fleeing first to Paris and then to London. There she met Mayer, who brought her to Hollywood. She became a star—and the iconic beauty of her screen generation (see Figure 8.4).

In 1940, Lamarr arranged to meet Antheil. Her upper torso could use some enhancement, she thought, and she hoped Antheil could give her some advice. Antheil was a self-styled expert on female endocrinology, and had written a series of articles for *Esquire* magazine with titles such as "The Glandbook for the Questing Male." Antheil suggested glandular extracts. Their conversation then turned to other matters—specifically, to torpedo warfare.

A torpedo—just a bomb with a propeller—could sink a massive ship. Radio-controlled torpedoes had been developed by the end of World War I, but were far from foolproof. An effective countermeasure was to jam the signal controlling the torpedo by broadcasting loud radio noise at the frequency of the control signal. The torpedo would go haywire and likely miss its target. From observing Mandl's business, Lamarr had learned about torpedoes and why it was hard to control them.

Lamarr had become fiercely pro-American and wished to help the Allied war effort. She conceived the idea of transmitting the torpedo control signal in short bursts at different frequencies. The code for the sequence of frequencies would be held identically within the torpedo and the controlling ship. Because the sequence would be unknown to the enemy, the transmission could not be jammed by flooding the airwaves with noise in any limited frequency band. Too much power would be required to jam all possible frequencies simultaneously.

FIGURE 8.4 Hedy Lamarr, at about the age when she and George Antheil made their spread spectrum discovery.

Antheil's contribution was to control the frequency-hopping sequence by means of a player piano mechanism—with which he was familiar because he had scored his masterpiece, *Ballet Mécanique*, for synchronized player pianos. As he and Lamarr conceived the device (it was never built), the signal would therefore hop among 88 frequencies, like the 88 keys on a piano keyboard. The ship and the torpedo would have identical piano rolls—in effect, encrypting the broadcast signal.

In 1941, Lamarr and Antheil assigned their patent (see Figure 8.5) to the Navy. A small item on the "Amusements" page of the *New York Times* quoted an army engineer as describing their invention as so "red hot" that he could not say what it did, except that it was "related to the remote control of apparatus employed in warfare." Nonetheless, the Navy seems to have done

> The story of Antheil and Lamarr, and the place of their invention in the history of spread spectrum, is told in *Spread Spectrum* by Rob Walters (Booksurge LLC, 2005).

nothing with the invention at the time. Instead, Lamarr went to work selling war bonds. Calling herself "just a plain gold-digger for Uncle Sam," she sold kisses, and once raised $4.5 million at a single lunch. The patent was ignored for more than a decade. Romuald Ireneus 'Scibor-Marchocki, who was an engineer for a Naval contractor in the mid-1950s, recalls being given a copy when he was put to work on a device for locating enemy submarines. He didn't recognize the patentee because she had not used her stage name.

UNITED STATES PATENT OFFICE

2,292,387

SECRET COMMUNICATION SYSTEM

Hedy Kiesler Markey, Los Angeles, and George Antheil, Manhattan Beach, Calif.

Application June 10, 1941, Serial No. 397,412

6 Claims. (Cl. 250—2)

This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies, and is especially useful in the remote control of dirigible craft, such as torpedoes.

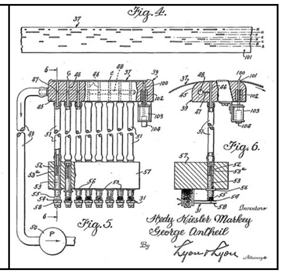
An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.

Fig. 2 is a schematic diagram of the apparatus at a receiving station;

Fig. 3 is a schematic diagram illustrating a starting circuit for starting the motors at the transmitting and receiving stations simultaneously;

Fig. 4 is a plan view of a section of a record strip that may be employed;

Fig. 5 is a detail cross section through a rec-



U.S. Patent Office.

FIGURE 8.5 Original spread spectrum patent by Hedy Lamarr (*née* Kiesler—Gene Markey was her second husband, of six) and George Antheil. On the left, the beginning of the patent itself. On the right, a diagram of the player-piano mechanism included as an illustration in the patent.

And that, in a nutshell, is the strange story of serendipity, teamwork, vanity, and patriotism that led to the Lamarr-Antheil discovery of spread spectrum. The connection of these two to the discovery of spread spectrum was made only in the 1990s. By that time, the influence of their work had become entangled with various lines of classified military research. Whether Hedy Lamarr was more a Leif Erikson than a Christopher Columbus of this new conceptual territory, she was surely the most unlikely of its discoverers. In 1997, the Electronic Frontier Foundation honored her for her discovery; she welcomed the award by saying, "It's about time." When asked about her dual achievements, she commented, "Films have a certain place in a certain time period. Technology is forever."

Channel Capacity

Lamarr and Antheil had stumbled on a particular way of exploiting a broad frequency range—"spreading" signals across the spectrum. The theoretical foundation for spread spectrum was one of the remarkable mathematical results of Claude Shannon in the late 1940s. Although no digital telephones or radios existed at the time, Shannon derived many of the basic laws by which they would have to operate. The Shannon-Hartley Theorem predicted spread spectrum in the same way that Maxwell's equations predicted radio waves.

Shannon's result (building on work by Ralph Hartley two decades earlier) implies that "interference" is not the right concept for thinking about how much information can be carried in the radio spectrum. Signals can overlap in frequency and yet be pulled apart perfectly by sufficiently sophisticated radio receivers.

Early engineers assumed that communication errors were inevitable. Send bits down a wire, or through space using radio waves, and some of them would probably arrive incorrectly, because of noise. You could make the channel more reliable by slowing the transmission, they supposed, in the same way that people talk more slowly when they want to be sure that others understand them—but you could never guarantee that a communication was errorless.

Shannon showed that communication channels actually behave quite differently. Any communication channel has a certain *channel capacity*—a number of bits per second that it can handle. If your Internet connection is advertised as having a bit rate of 3Mbit/sec (3 million bits per second), that number is the channel capacity of the particular connection between you and your Internet Service Provider (or should be—not all advertisements tell the truth). If the connection is over telephone wiring and you switch to a service that runs over fiber optic cables, the channel capacity should increase.

However large it is, the channel capacity has a remarkable property, which Shannon proved: Bits can be transmitted through the channel, from the source to the destination, *with negligible probability of error* as long as the transmission rate does not exceed the channel capacity. Any attempt to push bits down the channel at a rate higher than the channel capacity will inevitably result in data loss. With sufficient cleverness about the way data from the source is encoded before it is put in the channel, the error rate can be essentially zero, as long as the channel capacity is not exceeded. Only if the data rate exceeds the channel capacity do transmission errors become inevitable.

Errors and Delays

Although transmission errors can be made unlikely, they are never impossible. However, errors can be made far less probable than, for example, the death of the intended recipient in an earthquake that just happens to occur while the bits are on their way (see the Appendix). Guaranteeing correctness requires adding redundant bits to the message—in the same way that fragile postal shipments are protected by adding styrofoam packing material. Attaining data rates close to the "Shannon limit" involves pre-processing the bits. That may increase *latency*—the time delay between the start of the "packing" process and the insertion of bits into the channel. Latency can be a problem in applications such as voice communication, where delays annoy the communicants. Happily, phone calls don't require error-free transmission—we are all used to putting up with a little bit of static.

Power, Signal, Noise, and Bandwidth

The capacity of a radio channel depends on the frequencies at which messages are transmitted and the amount of power used to transmit them. It's helpful to think about these two factors separately.

Bandwidth

Because channel capacity depends on frequency bandwidth, the term "bandwidth" is used informally to mean "amount of information communicated per second." But technically, bandwidth is a term about electromagnetic communication, and even then is only one of the factors affecting the capacity to carry bits.

A radio broadcast is never "at" a single frequency. It always uses a range or *band* of frequencies to convey the actual sounds. The only sound that could be carried at a single, pure frequency would be an unvarying tone. The *bandwidth* of a broadcast is the size of the frequency band—that is, the difference between the top frequency and the bottom frequency of the band. Hoover, to use this language, allotted 10kHz of bandwidth for each AM station.

If you can transmit so many bits per second with a certain amount of bandwidth, you can transmit twice that many bits per second if you have twice as much bandwidth. The two transmissions could simply go on side by side, not interacting with each other in any way. So, *channel capacity is proportional to bandwidth.*

The relation to signal power is more surprising. To use simple numbers for clarity, suppose you can transmit one bit, either 0 or 1, in one second. If you could use *more power* but *no more time or bandwidth*, how many bits could you transmit?

One way a radio transmission might distinguish between `0` and `1` is for the signals representing these two values to have different signal powers. To continue to oversimplify, assume that zero power represents `0`, and a little more power, say 1 watt, represents `1`. Then to distinguish a `1` from a `0`, the radio receiver has to be sensitive enough to tell the difference between 1 watt and 0 watts. The uncontrollable noise—radio waves arriving from sunspots, for example—also must be weak enough that it does not distort a signal representing `0` so that it is mistaken for a signal representing `1`.

Under these conditions, four times as much power would enable transmission of two bits at once, still in one second. Power level 0 could represent `00`; 1 watt, `01`; 2 watts, `10`; and 3 watts could represent `11`. Successive power levels have to be separated by at least a watt to be sure that one signal is not confused with another. If the power levels were closer together, the unchanged noise might make them impossible to distinguish reliably. To transmit three bits at a time, you'd need eight times as much power, using levels 0 through 7 watts—that is, the amount of power needed increases exponentially with the number of bits to be transmitted at once (see Figure 8.6).

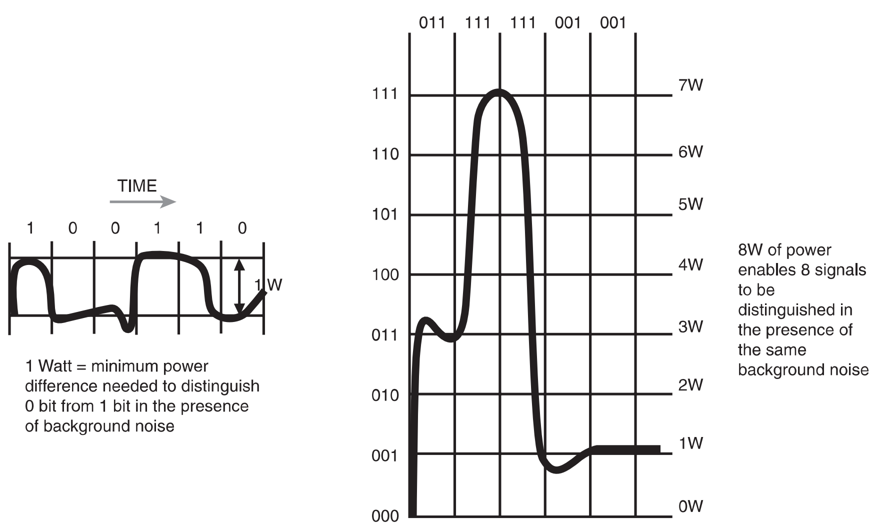


FIGURE 8.6 Shannon-Hartley. Signal levels must be far enough apart to be distinguishable in spite of the distortion caused by noise. Tripling the bit rate requires eight times as much power.

So the Shannon-Hartley result says that *channel capacity depends on both bandwidth and signal power*, but *more bandwidth is exponentially more valuable than more signal power*. You'd have to get more than *a thousand times* more signal power to get the same increase in channel capacity as you could get from having just ten times more bandwidth (because $1024 = 2^{10}$). Bandwidth is precious indeed.

One Man's Signal Is Another Man's Noise

The consequences of the Shannon-Hartley result about the value of bandwidth are quite astonishing. If WBZ were transmitting digitally with its 50,000 watt transmitter, it could transmit the same amount of information (over shorter distances) using less power than a household light bulb—if it could get 100kHz of bandwidth rather than the 10kHz the FCC has allowed it.

Of course, no station could get exclusive use of 100kHz. Even giving each station 10kHz uses up the spectrum too quickly. The spectrum-spreading idea works only if the spectrum is regarded as a commons. And to see the consequences of many signals broadcasting in the same spectrum, one more crucial insight is needed.

The power level that affects the capacity of a radio channel is not actually the signal power, but the ratio of the signal power to the noise power—the so-called *signal-to-noise ratio*. In other words, you could transmit at the same bit rate with one watt of power as with ten—*if* you could also reduce the noise by a factor of ten. And *"noise" includes other people's signals*. It really doesn't matter whether the interference is coming from other human broadcasts or from distant stars. All the interfering broadcasts can share the same spectrum band, to the extent they could coexist with the equivalent amount of noise.

> A readable account of spread spectrum radio appeared in 1998: "Spread-Spectrum Radio" by David R. Hughes and DeWayne Hendricks (*Scientific American*, April 1998, 94–96).

A surprising consequence of Shannon-Hartley is that *there is some channel capacity even if the noise (including other people's signals) is stronger than the signal.* Think of a noisy party: You can pick out a conversation from the background noise if you focus on a single voice, even if it is fainter than the rest of the noise. But the Shannon-Hartley result predicts even more: *The channel can transmit bits flawlessly, if slowly, even if the noise is many times more powerful than the signal. And if you could get a lot of bandwidth, you could drastically reduce the signal power* *without lowering the bit rate at all* (see Figure 8.7). What would seem to be just noise to anyone listening casually on a particular frequency would actually have a useful signal embedded within it.

The Shannon-Hartley Theorem is a mathematician's delight—a tease that limits what is possible in theory and gives no advice about how to achieve it in practice. It is like Einstein's $E = mc^2$—which at once says nothing, and everything, about nuclear reactors and atomic bombs. Hedy Lamarr's frequency hopping was one of the spread spectrum techniques that would eventually be practical, but other ingenious inventions, named by odd acronyms, would emerge in the late twentieth century.

Two major obstacles stood between the Shannon-Hartley result and usable spread spectrum devices. The first was engineering: computers had to become fast, powerful, and cheap enough to process bits for transmission of high-quality audio and video to consumers. That wouldn't happen until the 1980s. The other problem was regulatory. Here the problem was not mathematical or scientific. Bureaucracies change more slowly than the technologies they regulate.

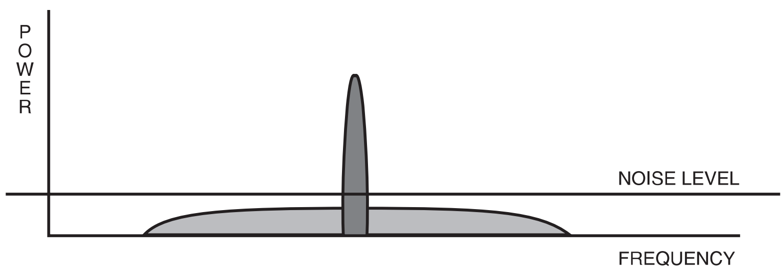


FIGURE 8.7 The spread spectrum principle. The same bit rate can be achieved at much lower power by using more bandwidth, and the signal power can even be less than the noise.

Spectrum Deregulated

Today, every Starbucks has WiFi—that is, wireless Internet access. Hotel rooms, college dormitories, and a great many households also have "wireless." This happened because a tiny piece of the spectrum, a slice less than a millimeter wide in Figure 8.1, was deregulated and released for experimental use by creative engineers. It is an example of how deregulation can stimulate industrial innovations, and about how existing spectrum owners prefer a regulatory climate that maintains their privileged position. It is a story that could be repeated elsewhere in the spectrum, if the government makes wise decisions.

Michael Marcus is an improbable revolutionary. An MIT-trained electrical engineer, he spent three years as an Air Force officer during the Vietnam war, designing communications systems for underground nuclear test detection at a time when the ARPANET—the original, military-sponsored version of the Internet—was first in use. After finishing active duty, he went to work at a Pentagon think tank, exploring potential military uses of emerging communications technologies.

In the summer of 1979, Marcus attended an Army electronic warfare workshop. As was typical at Army events, attendees were seated alphabetically. Marcus's neighbor was Steve Lukasik, the FCC's chief scientist. Lukasik had been Director of ARPA during the development of the ARPANET and then an ARPANET visionary at Xerox. He came to the FCC, not generally considered a technologically adventurous agency, because Carter administration officials were toying with the idea that existing federal regulations might be stifling innovation. Lukasik asked Marcus what he thought could stimulate growth in radio communications. Marcus answered, among other things, "spread spectrum." His engineering was sound, but not his politics. People would not like this idea.

The military's uses of spread spectrum were little known to civilians, since the Army likes to keep its affairs secret. The FCC prohibited all civil use of spread spectrum, since it would require, in the model the Commission had used for decades, trespassing on spectrum bands of which incumbents had been guaranteed exclusive use. Using lots of bandwidth, even at low power levels, was simply not possible within FCC regulations. Lukasik invited Marcus to join the FCC, to champion the development of spread spectrum and other innovative technologies. That required changing the way the FCC had worked for years.

Shortly after the birth of the Federal Radio Commission, the U.S. plummeted into the worst depression it had ever experienced. In the 1970s, the FCC was still living with the culture of the 1930s, when national economic policies benevolently reined in free-market capitalism. As a general rule, innovators hate regulation, and incumbent stakeholders love it—when it protects their established interests. In the radio world, where spectrum is a limited, indispensable, government-controlled raw material, this dynamic can be powerfully stifling.

Incumbents, such as existing radio and TV stations and cell phone companies, have spectrum rights granted by the FCC in the past, perhaps decades ago, and renewed almost automatically. Incumbents have no incentive to allow use of "their" spectrum for innovations that may threaten their business. Innovators can't get started without a guarantee from regulators that they will be granted use of spectrum, since investors won't fund businesses reliant on resources the government controls and may decide not to provide.

Regulators test proposals to relax their rules by inviting public comment, and the parties they hear from most are the incumbents—who have the resources to send teams to lobby against change. Their complaints predict disaster if the rules are relaxed. In fact, their doomsday scenarios are often exaggerated in the hope the regulators will exclude competition. Eventually, the regulators lose sight of their ultimate responsibility, which is to the public good and not to the good of the incumbents. It is just easier to leave things alone. They can legitimately claim to be responding to what they are being told, however biased by the huge costs of travel and lobbying. Regulatory powers meant to prevent electromagnetic interference wind up preventing competition instead.

And then there is the revolving door. Most communications jobs are in the private sector. FCC employees know that their future lies in the commercial use of the spectrum. Hundreds of FCC staff and officials, including all eight past FCC chairmen, have gone to work for or represented the businesses they regulated. These movements from government to private employment violate no government ethics rules. But FCC officials can be faced with a choice between angering a large incumbent that is a potential employer, and disappointing a marginal start-up or a public interest non-profit. It is not surprising that they remember that they will have to earn a living after leaving the FCC.

In 1981, Marcus and his colleagues invited comment on a proposal to allow low-power transmission in broad frequency bands. The incumbents who were using those bands almost universally howled. The FCC beat a retreat and attempted, in order to break the regulatory logjam, to find frequency bands where there could be few complaints about possible interference with other uses. They hit on the idea of deregulating three "garbage bands," so called because they were used only for "industrial, scientific, and medical" (ISM) purposes. Microwave ovens, for example, cook food by pummeling it with 2.450GHz electromagnetic radiation. There should have been no complaints—microwave ovens were unaffected by "interference" from radio signals, and the telecommunications industry did not use these bands.

RCA and GE complained anyway about possible low-power interference, but their objections were determined to be exaggerated. This spectrum band was opened to experimentation in 1985, on the proviso that frequency hopping or a similar technique be used to limit interference.

Marcus did not know what might develop, but engineers were waiting to take advantage of the opportunity. Irwin Jacobs founded QUALCOMM a few months later, and by 1990, the company's cell phone technology was in widespread use, using a spread spectrum technique called CDMA. A few years later, Apple Computer and other manufacturers agreed with the FCC on standards to use spread spectrum for radio local area networks—"wireless routers," for which Apple's trademarked device is called the Airport. In 1997, when the FCC approved the 802.11 standard and the spectrum bands were finally available for use, the press barely noticed. Within three years, wireless networking was everywhere, and virtually all personal computers now come ready for WiFi.

> Michael Marcus's web site, `www.marcus-spectrum.com`, has interesting materials, and opinions, about spectrum deregulation and spread spectrum history.

For his efforts, Marcus was sent into internal exile within the FCC for seven years but emerged in the Clinton era and returned to spectrum policy work. He is now retired and working as a consultant in the private sector.

The success of WiFi has opened the door to discussion of more radical spectrum-spreading proposals. The most extreme is UWB—"ultra wide band" radio. UWB returns, in a sense, to Hertz's sparks, splattering radiation all across the frequencies of the radio spectrum. There are two important differences, however. First, UWB uses extremely low power—feasible because of the very large bandwidth. Power usage is so low that UWB will not interfere with any conventional radio receiver. And second, UWB pulses are extremely short and precisely timed, so that the time between pulses can symbolically encode a transmitted digital message. Even at extremely low power, which would limit the range of UWB transmissions to a few feet, UWB has the potential to carry vast amounts of information in short periods of time. Imagine connecting your high definition TV, cable box, and DVD player without cables. Imagine downloading your library of digital music from your living room audio system to your car while it is parked in your garage. Imagine wireless video phones that work better than wired audio phones. The possibilities are endless, if the process of regulatory relaxation continues.

What Does the Future Hold for Radio?

In the world of radio communications, as everywhere in the digital explosion, time has not stopped. In fact, digital communications have advanced less far than computer movie-making or voice recognition or weather prediction, because only in radio does the weight of federal regulation retard the explosive increase in computational power. The deregulation that is possible has only begun to happen.

What If Radios Were Smart?

Spread spectrum is a way of making better use of the spectrum. Another dramatic possibility comes with the recognition that ordinary radios are extremely stupid by comparison with what is computationally possible today. If taken back in time, today's radios could receive the broadcasts of 80 years ago, and the AM radios of 80 years ago would work as receivers of today's broadcasts. To achieve such total "backward compatibility," a great deal of efficiency must be sacrificed. The reason for such backward compatibility is not that many 80-year-old radios are still in service. It's that *at any moment in time*, the incumbents have a strong interest in retaining their market share, and therefore, in lobbying against efforts to make radios "smarter" so more stations can be accommodated.

If radios were intelligent and active, rather than dumb and passive, vastly more information could be made available through the airwaves.

If radios were intelligent and active, rather than dumb and passive, vastly more information could be made available through the airwaves. Rather than broadcasting at high power so that signals could travel great distances to reach passive receivers, low-power radios could pass signals on to each other. A request for a particular piece of information could be transmitted from radio to radio, and the information could be passed back. The radios could cooperate with each other to increase the information flux received by all of them. Or multiple weak transmitters could occasionally synchronize to produce a single powerful beam for long-range communication.

> **WHAT DOES "SMART" MEAN?**
>
> "Intelligent" or "smart" radio goes by various technical names. The two most commonly used terms are "software-defined radio" (SDR) and "cognitive radio." Software-defined radio refers to radios capable of being reprogrammed to change characteristics usually implemented in hardware today (such as whether they recognize AM, FM, or some other form of modulation). Cognitive radio refers to radios that use artificial intelligence to increase the efficiency of their spectrum utilization.

Such "cooperation gains" are already being exploited in *wireless sensor networking*. Small, low-power, radio-equipped computers are equipped with sensors for temperature or seismic activity, for example. These devices can be scattered in remote areas with hostile environments, such as the rim of a smoldering volcano, or the Antarctic nesting grounds of endangered penguins. At far lower cost and greater safety than human observers could achieve, the devices can exchange information with their neighbors and eventually pass on a summary to a single high-power transmitter.

There are vast opportunities to use "smart" radios to increase the number of broadcast information options—if the regulatory stranglehold on the industry can be loosened and the incentives for innovation increased.

Radios can become "smarter" in another respect. Even under the "narrowband" model for spectrum allocation, where one signal occupies only a small range of frequencies, cheap computation can make a difference. The very notion that it is the government's job to prevent "interference," enshrined in legislation since the 1912 Radio Act, is now anachronistic.

Radio waves don't really "interfere," the way people in a crowd interfere with each other's movements. The waves don't bounce off each other; they pass right through each other. If two different waves pass through the antenna of a dumb old radio, neither signal can be heard clearly.

To see what might be possible in the future, ask a man and a woman to stand behind you, reading from different books at about the same voice level. If you don't focus, you will hear an incoherent jumble. But if you concentrate on one of the voices, you can understand it and block out the other. If you shift your focus to the other voice, you can pick that one out. This is possible because your brain performs sophisticated signal processing. It knows something about male and female voices. It knows the English language and tries to match the sounds it is hearing to a lexicon of word-sounds it expects English speakers to say. Radios could do the same thing—if not today, then soon, when computers become a bit more powerful.

But there is a chicken-and-egg cycle. No one will buy a "smart" radio unless there is something to listen to. No one can undertake a new form of broadcasting without raising some capital. No investor will put up money for a project that is dependent on uncertain deregulation decisions by the FCC. Dumb radios and inefficient spectrum use protect the incumbents from competition, so the incumbents lobby against deregulation.

Moreover, the incumbent telecommunications and entertainment industries are among the leading contributors to congressional election campaigns. Members of Congress often pressure the FCC to go against the public interest and in favor of the interests of the existing stakeholders. This problem was apparent even in the 1930s, when an early history of radio regulation stated, "no quasi-judicial body was ever subject to so much congressional pressure as the Federal Radio Commission." The pattern has not changed.

In other technologies, such as the personal computer industry, there is no such cycle. Anyone who wants to innovate needs to raise money. Investors are inhibited by the quality of the technology and the market's expected reaction to it—but not by the reactions of federal regulators. Overextended copyright protections have chilled creativity, as was discussed in Chapter 6, but lawmakers are to blame for that problem, not unelected commissioners.

From cell phones to wireless routers to keychain auto locks, wireless innovations are devoured by the public, when they can be brought to market at all. To foster innovation, the regulatory stranglehold needs to be broken throughout the wireless arena, including broadcast technologies. The regulations are now the source of the scarcity that is used to justify the regulations!

TV, ENTERTAINMENT, AND CONGRESS

In the 2006 election campaigns, the TV, movie, and music industries contributed more than $12 million to the re-election campaigns of incumbents, more than the oil and gas industry. The three biggest contributors were Comcast Corp., Time Warner, and the National Cable and Telecommunications Association.

The regulations are now the source of the scarcity that is used to justify the regulations!

But Do We Want the Digital Explosion?

Technologies converge. In 1971, Anthony Oettinger foresaw the line blurring between computing and communications. He called the emerging single technology "compunication." Today's computer users don't even think about the fact that their data is stored thousands of miles away—until their Internet connection fails. Telephones were first connected using copper wires, and television stations first broadcast using electromagnetic waves, but today most telephone calls go through the air and most television signals go through wires.

Laws, regulations, and bureaucracies change much more slowly than the technologies they govern. The FCC still has separate "Wireless" and "Wireline" bureaus. Special speech codes apply to "broadcast" radio and television, although "broadcasting" is an engineering anachronism.

The silo organization of the legal structures inhibits innovation in today's layered technologies. Regulation of the content layer should not be driven by an outdated understanding of the engineering limits of the physical layer. Investments made in developing the physical layer should not enable the same companies to control the content layer. The public interest is in innovation and efficiency; it is not in the preservation of old technologies and revolving doors between regulators and the incumbents of the regulated industry.

But if the spectrum is freed up—used vastly more efficiently than it now is, and made available for innovative wireless inventions and far more "broadcast" channels—will we like the result?

There are general economic and social benefits from innovations in wireless technology. Garage door openers, Wiis, and toll booth transponders do not save lives, but wireless fire detectors and global positioning systems do. The story of WiFi illustrates how rapidly an unforeseen technology can become an essential piece of both business and personal infrastructure.

But what about television and radio? Would we really be better off with a million channels than we were in the 1950s with 13, or are today with a few hundred on satellite and cable? Won't this profusion of sources cause a general lowering of content quality, and a societal splintering as *de facto* authoritative information channels wither? And won't it become impossible to keep out the smut, which most people don't want to see, whatever the rights of a few?

As a society, we simply have to confront the reality that our mindset about radio and television is wrong. It has been shaped by decades of the scarcity argument. That argument is now brain-dead, kept breathing on artificial life support by institutions that gain from the speech control it rationalizes. Without the scarcity argument, TV and radio stations become less like private leases on public land, or even shipping lanes, and more like ... books.

There will be a period of social readjustment as television becomes more like a library. But the staggering—even frightening—diversity of published literature is not a reason not to have libraries. To be sure, there should be determined efforts to minimize the social cost of getting the huge national investment in old TV sets retired in favor of million-channel TV sets. But we know how to do that sort of thing. There is always a chicken-and-egg problem when a new technology comes along, such as FM radios or personal computers.

When market forces govern what gets aired, we may *not* be happy with the results, however plentiful. But if what people want is assurance about what they *won't* see, then the market will develop channels without dirty words and technologies to lock out the others. The present system stays in place because of the enormous financial and political influence of the incumbents—and because the government likes speech control.

How Much Government Regulation Is Needed?

Certainly, where words end and actions begin, people need government protection. Dr. Brinkley lost his medical license, which was right then, and would be right today.

In the new wireless world, government needs to enforce the rules for spectrum sharing—technologies that can work only if everyone respects power and bandwidth restraints. The government has to ensure that manufactured devices obey the rules, and that rogues don't violate them. The government also has to help develop and endorse standards for "smart" radios.

It also has the ultimate responsibility for deciding if the dire warnings of incumbents about the risks imposed by new technologies are scientifically valid, and if valid, of sufficiently great social importance to block the advancement of engineering. A typical caution was the one issued in the fall of 2007 by the National Association of Broadcasters as it rolled out a national advertising campaign to block a new technology to locate unused parts of the TV spectrum for Internet service: "While our friends at Intel, Google, and Microsoft may find system errors, computer glitches, and dropped calls tolerable, broadcasters do not." Scientific questions about interference should be settled by science, not by advertisements or Congressional meddling. We will always need an independent body, like the FCC, to make these judgments rationally and in the public interest.

If all that happens, the scarcity problem will disappear. At that point, government authority over content should—and constitutionally *must*—drop back to the level it is at for other non-scarce media, such as newspapers and books. Obscenity and libel laws would remain in place for wireless communication as for other media. So would any other lawful restrictions Congress might adopt, perhaps for reasons of national security.

Other regulation of broadcast words and images should end. Its legal foundation survives no longer in the newly engineered world of information. There are too many ways for the information to reach us. We need to take responsibility for what we see, and what our children are allowed to see. And they must be educated to live in a world of information plenty.

There is no reason to re-establish a "Fairness Doctrine," like that which until 1987 required stations to present multiple points of view. If there were more channels, the government would not have any need, or authority, to second-guess the editorial judgment of broadcasters. Artificial spectrum scarcity has, in the words of Justice William O. Douglas, enabled "administration after administration to toy with TV or radio in order to serve its sordid or its benevolent ends." Justice Frankfurter's claim that "there is no room in the broadcast band for every business or school of thought" is now false.

* * *

Bits are bits, whether they represent movies, payrolls, expletives, or poems. Bits are bits, whether they are moved as electrons in copper wire, light pulses in glass fiber, or modulations in radio waves. Bits are bits, whether they are stored in gigantic data warehouses, on DVDs sent through the mail, or on flash drives on keychains. The regulation of free speech on broadcast radio and television is but one example of the lingering social effects of historical accidents of technology. There are many others—in telephony, for example. Laws and policies regulating information developed around the technologies in which that information was embodied.

The digital explosion has reduced all information to its lowest common denominator, sequences of `0`s and `1`s. There are now adapters at all the junctions in the world-wide networks of information. A telephone call, a personal letter, and a television show all reach you through the same mixture of media. The bits are shunted between radio antennas, fiber-optic switching stations, and telephone wiring many times before they reach you.

Bits are bits, whether they represent movies, payrolls, expletives, or poems.

The universality of bits gives mankind a rare opportunity. We are in a position to decide on an overarching view of information. We can be bound in the future by first principles, not historical contingencies. In the U.S., the digital explosion has blown away much of the technological wrapping obscuring the First Amendment. Knowing that information is just bits, all societies will be faced with stark questions about where information should be open, where it should be controlled, and where it should be banned.