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COMMUNICATIONS
FORUM

THE WIRELESS OFFICE

September 26, 1985

Seminar Notes

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Alex Felker
FCC

Payne Freret
Consultant

Kaveh Pahlavan
Worcester Polytechnic

THE WIRELESS OFFICE

Payne Freret - Consultant

Freret began by stating that in the context of the 'wireless office', the biggest problem faced by the radio signal is the indoor radio environment, by which he meant the multipath introduced in the radio signal by reflection from walls, filing cabinets, etc. In the ideal situation there is only one path between a transmitter and a receiver without interference and reflection. In the real case however, there are numerous paths occuring as a result of reflection. Therefore in a given geographical situation different frequencies encounter various amounts of attenuation while some actually experience re-enforcement. He said there are three ways in which the problem could be overcome. Firstly, to compensate the loss of power more powerful transmitters could be used. This is the conventional method that has been used for many years. Secondly, to overcome this spread problem, the band-width could be increased to spread the date over a wide band, such that only a small portion of the total power is lost. The rationale being that it is likely that most of the power gets through and communication is still possible. The third possibility is that of picking a frequency which does not suffer multipath cancellation. This takes some calibration and co-ordination with other users. The advantage here, is that instead of using fairly expensive and exotic spread spectrum devices, very cheap micro processors may be used. Of the above, the second and third approaches have as their objective the maintenance of lower power consumption. Therefore by doing this a re-use of the same frequency is possible in other areas nearby, may be even on the next floor. He said that in commercial areas this will have to be carefully co-ordinated since there could be a completely different organisation on the other side of the wall or on the next floor. Therefore it may necessitate getting the FCC involved.

Freret then explained two common forms of spread spectrums. One the Direct Sequence Spread Spectrum (DSSS) and the other the Frequency Hopping Spread Spectrum (FHSS). In the case of DSSS each single data bit is encoded by a more complicated pattern called the spreading code which is fairly easy to generate. In the case of the FHSS, instead of being mixed with the digital pattern as the direct sequence, the data bits modulate the frequency hopped carrier oscillator. He then concentrated on the DSSS which is the system that they had built. It has some advantages compared with the FHSS. The disadvantage in FHSS is that you have to know the sequence the transmitter is using in order to receive it. It is difficult to use in a commercial environment at low cost because synchronization has to be established at each receiver. In the DSSS as well, synchronization has to be established. In the conceptually simplest case, the same code is generated at the receiver which which tries to line it up with the signal received from the antenna. When the two codes get multiplied together they sort of neutralise each other releasing just the data. The drawback of this is that it also requires synchronisation. If there are different users transmitting from different points of the building the timing would be different for each one and re-establishing of synchronization will be required. Fortunately modern technology solves this problem. He went on to describe a Surface Acoustic Wave device as being made of piezo electric material which in many experiments that they had conducted was quartz having a low coupling constant. Though this meant a lot of signal loss, the advantage is that it has a very low temperature coefficient. He went on further to show several other slides and describe in some detail the device used and the method by which signals are received and decoded, without explicit synchronization.

He further said that the trouble with buildings is that there are more ways than one for a signal to reach the receiver. There are the signals that take a direct path to the receiver which may or may not be stronger than the several multipath signals. If a receiver was sensitive only to one path and could receive only one at a time then the operation would be on 'thin ice'. The interesting aspect of the spread spectrum is that it can combine signals from many paths. It is also good at rejecting CW interferences as well as from different codes, in multiaccess systems. It is possible to still make out clearly the wanted code from the unwanted ones. However, if one kept on adding different codes it would eventually be difficult to differenciate the code that is wanted from the stray codes.

He said that they began investigating spread spectrum with considerable hope, expecting with 60 milliwatts to cover the inside of a rather large building (1000 meters per side). Also they did not expect the FCC to interfere at that signal level. They soon found out that it had to be considerably weaker than 60 milliwatts before the FCC turns the other way. One of the problems he said is something called the near far problem. It shows up because they would like to operate at very low power, in order to avoid "blasting all the windows in the building". The drawback is that particularly in case of DSSS using a wide band width allows any CW signal within the bandwidth can enter the radio. Of course this can be reduced by coding but not entirely, specially if the CW signal is very strong.

In closing Freret said that multipath interferences could be rejected in certain receivers, and spread spectrum could yield gains to signal reception. He said in short there was no distinct advantage of spread systems over selected narrow band signals except when there was interference. The benefit in the use of spread systems was not as good as they originally anticipated it to be, 6-7 years ago.

ALEX FELKER - FCC

Alex Felker focused his remarks on the question of spectrum availability for wireless office systems. In analyzing this issue, he briefly reviewed two industry proposals for radio based data systems and discussed some related FCC proceedings.

Firstly he considered the Motorola proposal for an exclusive 10 MHz allocation at 1.7 GHz to link PCs in an office environment. Only a minimum of technical regulation is suggested: 100 milliwatt maximum power and out of band emission restrictions. All other technical parameters are left unspecified to encourage the development of alternate systems using any modulation technique. The FCC he said was considering whether and how to structure a formal rule making, to explore further the desirability of an exclusive allocation for radio based LAN's. He said he found the proposal intriguing, because Motorola's major argument was related to the reduction of costs rather than whether the service could be adequately provided over wire. The question before the commission was whether exclusive assignments should be made. Exclusivity though it guarantees higher quality may end up denying access to many users. He said that unless someone could design a viable system operating above 20 GHz any exclusive allocation would be pretty small. Some commentators he said, suggested that the FCC should restrict the uses to which frequencies may be put in order to limit congestion and interference in the band. However, this may be a case of "cutting the nose to spite the face", as has been seen in other allocations. For instance, prohibiting inter connection of radio systems and landlines could reduce loading but at the same time it would make the system less useful.

Secondly, two years ago the FCC was requested permission by Hewlett-Packard (HP) to experiment with spread spectrum wireless data systems. It was initially to be developed as a control link which for one reason or other could not be economically cabled. Though the commission never acted on this specific request, it authorised spread spectrum under two different rules. First, the use of frequency hopped systems on a limited basis by the Police Radio Service. Authorisation of direct sequence and other systems were first deferred, pending further evaluation of the interference potential. Second, FCC authorized them in low power spread spectrum usage in three bands now populated by industrial, scientific, and medical equipment.

Regulation he said, often favors the status quo and new technologies therefore face an uphill battle to obtain approval. However there was a recent proposal by the FCC, to make it easier for the new tecnnologies to be authorised in the two way radio service. Under the new proposal, most technical changes could be brought out to market without a rulemaking. Instead, an assessment of the proposed technique's interference potential would be made as part of the equipment authorisation process. Relative transmitting powers of new systems would be reduced to compensate for any increase in interference potential. Rule making may be still required to more fully evaluate the new system's maximum power level, but equipment could be licensed on a primary basis, pending the outcome of these proceedings.

Felker said that the philosophy of giving users greater flexibility was also finding its way into the FCC's approach to spectrum allocation. Under the traditional system, block allocations were made for specific services on a nation wide basis. This had its advantages. First it allowed the commission to reserve spectrum for important services and future demands (e.g. public safety and UHF TV services). Second, since the block approach pools similar uses into the same frequency band, it has been relatively easy to develop co-ordination procedures to avoid interference. Third, the block system may provide an increase in design certainty for equipment manufacturers. Pressures on available spectrum, he pointed out, arise from many sources (e.g. computer communications technology, mobile communications, and entertainment). As a result there is serious competition among various claimants for spectrum. Historically the FCC relied on intuition and expertise to judge the merits of requests. This worked tolerably well as long as there was unused spectrum available. For in a sense, there was no need to make a choice. Those days are long passed and though the commission will continue to make spectrum available for socially worthy services such as public safety, most spectrum competitors cannot easily be ranked on the same social yardstick. As a result the FCC has to choose from attractive but mutually exclusive communication services without any hard evidence of consumer demand. Consequently he said, the traditional approach may well preclude many socially desirable communication services. The traditional allocation process also does not adequately account for regional variations in spectrum use. For example, it seems inefficient to reserve huge amounts of spectrum for video distribution in areas where CATV penetration is high. He therefore said that proposals that do not neatly fit existing regulatory definitions or constitute an economic threat face, significant delays. In this context he suggested that wireless data systems may find this disadvantage one of its biggest problems. Felker reiterated however, that changes were coming. In a number of proceedings the FCC had either proposed or adopted rules to improve the process by shifting some allocation decisions to licensees. For example, broadcasters are now permitted to offer a variety of non-broadcast services on aural subcarriers and on the vertical blanking intervals of TV signals.

In closing, Felker said that the FCC is pursuing two goals in all these actions. First, it is trying to encourage the wise use of spectrum. Because flexibility places an explicit price on the resource, less of it should be wasted. In addition there will be a greater pay-off for those who developed systems that make more economic use of spectrum. Secondly, it is trying to achieve a more optimal allocation structure i.e. one that would respond dynamically to changes in demand for spectrum.

Kaveh Pahlavan - Worcester Polytechnic Institute

Pahlavan began by stating the advantages of using infra-red (IR), as opposed to other radio frequencies for office communications. IR does not interfere with any existing radio frequency systems and is also not restricted by FCC regulations. The IR radiation is restricted to the room in which it is used and it therefore cannot be detected outside the office. This provides a desired level of security and confidentiality and does not interfere with any similar system in neighboring offices. He then used a slide to show the sensitivities of the eye and silicon detectors to radiation in the UV/IR spectrum regions. Silicon detectors were sensitive to infra-red radiation though the eye was not. IR he said, has been used for several types of wireless communication, the commonest being remote-control which has been used since 1970. Voice related uses of IR include audio teleconferencing with wireless microphones, hearing aids for large conferences, together with multilingual conferencing with wireless headsets. Wireless phones and intra-shuttle audio communication have also used infra-red radiation. All of the above relate to analog or slow speed data communication. From the point of view of high speed data communication IR has been used for wireless computer keyboards mostly at the experimental stage. No product has yet been marketed.

Pahlavan went on to describe limitations encountered in the use of IR for wireless office communication. Firstly, there is the high incidence of multipath due to radiation being reflected off office walls and furniture. Multipath is capable of altering the radiation propagation. Secondly, there is the interference caused by ambient light (i.e. fluorescent light, incandescent light and daylight) resulting in the overload of the receiver photo diode. Thirdly, there is the limitation due to LED rise and fall times.

He then detailed possible applications of different modulation schemes in a IR communication link. These modulation schemes are described as analog, pulse, and digital modulation techniques. Modulation in IR communication usually takes place in two stages. That is, the transmitted message modulates a carrier and then the modulated signal amplitude (intensity) modulates the emited IR light. In practice no type of direct amplitude modulation by the message is used because IR links suffer from extensive amplitude fluctuations.

Most indoor applications he said, use analog modulation for audio signals. Modulating the message on a carrier shifts the spectrum of the signal away from the spectrum of the ambient light, providing an opportunity for multi-user applications, using frequency division multiplexing (FDM) as is used for simultaneous interpretation in multi-lingual conferences. Since amplitude modulation is not suitable for IR links, audio signals may frequency modulate a carrier. The resulting signal then intensity modulates the IR light.

Analog signals (such as voice) can be sampled and transmitted using analog pulse modulation techniques such as pulse amplitude modulation (PAM), pulse duration modulation (PDM), or pulse position modulation (PPM). Since PAM is amplitude modulation it is not suitable for infra-red links. He quoted the example of Siemen's AG who had used the PPM technique for a cordless infra-red telephone system. The signals used in the above system may also be quantized in digits to form a digital pulse modulation signal such as pulse code modulation, where the non return to zero (NRZ) data is Manchester coded and the result can be used to intensity modulate the IR light. The spectrum of the coded signal he said, includes weak low frequency components and it is possible to filter out ambient light interferences at these frequencies. Manchester coding though it provides a better time extraction doubles the transmission pulse rate.

Pahlavan further described what he called the most commonly used non amplitude modulation systems. Namely PSK and FSK, where terminal information is usually in binary form. For efficient use of the channel band-width more band-width efficient modulation schemes such as multilevel PSK and FSK should be considered. Of course the choice adds to the complexity of the system. Both PSK and FSK are suitable for use in telephone channels or radio channels. Both are suitable for IR and have been tried experimentally by IBM in Zurich. The data in PSK is phase modulated over the transmitted IR signal. Similarly FSK has been and the data rates for these systems are in the region of 120-128 Kb/s.

He then went on to explain IR multiple access techiques, where in the multi-user environment multi-access method is needed, to provide transmission capacity for individual uses. Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Carrier Sense Multiple Access with Collision Detection (CSMA/CD). The first has been applied to the multilingual conference system described earlier. The problem in FDMA, is that there could be inter channel interference caused by non linearities of the system. However the problem is not too accute in voice related systems. TDMA has been investigated by IBM, but no particular product has been put on the market. CSMA/CD was used by IBM for a multiple access system developed in Zurich. It is an IR network using FSK modulation. However, again in this case no product has been marketed.

In closing, Pahlavan used a slide to compare IR spread systems and radio frequencies in the field of communication. The details are tabulated overleaf.

COMPARISON BETWEEN DIFFERENT SYSTEMS FOR

WIRELESS IN-HOUSE COMMUNICATION

	IR	IR/SS	RF	RF/SS
1.Interference with existing systems	none	none	large	small
2.Mobility(shadowing or fading)	good	good	better	best
3.Detectability outside the office	none	none	some	little
4.Range	low	low	medium	medium
5.Data Rate	low	low	medium	medium
6.Cost	low	high	medium	high
7.Affected by Ambient Light	yes	some	no	no
8.Interception Resistance	no	yes	no	yes
9.Random Multiplex Access	no	yes	no	yes
10.Selective Addressing	no	yes	no	yes

Speakers' Comments and Responses to Questions

Payne Freret - The first question to Freret addressed the effect of data rate on multipath. In reply Freret confirmed that the higher the rate the lower the vulnerability to multipath. On being asked about the jamming margin, he explained that for a jamming margin of 30 db a processing gain of approximately 40 db is required, which is a code 10,000 'chips' long. The length of a 1000 'chip' device is already about 12 cms. He then referred to the process for producing a 'chip' - by exposing sillicon or quartz with the use of masking. In response to a question he went on to comment on reports of Japanese diversity FM receiver that had antennnas on the hood of the truck, which apparently improved multipath problems. He said that they had a multipath diversity receiver, not really a frequency diversity but a phase diversity system that they could rely on for the multipath off a wall. However, he said that they were interested in a small low cost unit that could be installed inside a terminal to make it completely portable. This they have not achieved as yet. At the time they were originally investigating this facility the FCC did not allow something like this and there was no way they could fit it into any existing FCC guideline. This project he said was currently 'on hold'.

The last question addressed to Freret was regarding the nature of antennas for which he responded saying that he had argued successfully from the beginning for an omni-directional antenna primarily because using this would not limit the direction of the source. However he said that the directional antenna had a significant advantage particularly in the power that is saved, and an advantage of less importance the reduction of interference.

Alex Felker - On being asked about the use of the frequency hop system on a limited basis by the police radio service, he said that FCC's field inspectors found it much easier to locate frequency hopped systems rather than direct sequence and other systems. It was for this reason that as an initial step they decided to test with the frequency hopped system. He believed that in some other countries commercial equipment that used frequency hopped systems was available. The FCC's intention was to use this limited authorization to the police service, as a testing ground for the interference environment.

In response to a further question he stated that by law the FCC is required to accept all comments made by the public and and use them in their decision making process. But he said since the FCC is very slow, very deliberate, and very status quo oriented, it causes them to be very cautious about the comments that are received.
