REPORT 1020

ADAPTATION OF SYSTEM SPECIFICATION TO EASE THE PRACTICAL IMPLEMENTATION OF RADIO EQUIPMENT

(Question 68/8)

(1986)

1. Introduction

Question 68/8 addresses the possibilities of adapting the technical characteristics of cellular land mobile radio systems (see Report 740) to ease their practical implementation without compromising the system performance. One of the most important system characteristics is good spectrum utilization.

Large systems, based on small-cell structures and allocated an exclusive frequency band, will be of growing importance, at present mainly for mobile telephone use but eventually also for dispatch and data services. A future mobile telephone system might also be integrated with the planned ISDN network.

In advanced cellular systems, mutual interference within the system can be reduced through suitable network arrangements, thus permitting reduced system selectivity (spurious, intermodulation, blocking) with marginal impact on the overall system performance. New technologies such as digital speech transmission and time divided usage of wide-band radio channels (TDMA, packet transmission and time duplex) could be used in new system configurations with improved performance in comparison with present analogue narrow-band systems. Potential improvements are in spectrum economy, transmission quality, new services and ease of implementation.

Small portable terminals will probably be of rapidly growing importance if cost and size can be made attractive for a mass market. It is therefore very desirable that the system specification and configuration ease the implementation of small, inexpensive terminals. The combination of digital transmission, reduced system selectivity and wide-band radio channels could make this possible.

Most of the material in this Report has been presented in more detail in four contributions to the Nordic Seminar on Digital Land Mobile Radiocommunication in Finland, February, 1985 organized by the Telecommunication Administrations of Denmark, Finland, Norway and Sweden [Öhrvik, 1985; Stjernvall, 1985; Ekemark *et al.*, 1985; Uddenfeldt, 1985; Uddenfeldt and Stjernvall, 1985].

Uddenfeldt [1985] discusses the relations between system characteristics and ease of implementation. A more detailed discussion can be found in lecture notes from a post-graduate course held at Lund University, Sweden, in 1984 [Öhrvik, 1984].

2. Comparison between the frequency economy of narrow-band digital speech transmission and present analogue mobile telephone systems

Several research groups have indicated that speech coders of reasonable complexity and power consumption (for portable telephones) could give close to normal telephony speech quality with a total data rate of around 16 kbit/s, including channel coding to accept up to 1% bit error ratio with small degradation in speech quality. Additional channel coding against burst errors due to fading dips, which increases the data rate to around 27 kbit/s, gives a substantial reduction of the required $C/I_{co\text{-}channel}$ during Rayleigh fading. 27 kbit/s can be transmitted over a 25 kHz radio channel with reduced requirements on adjacent-channel attenuation. The reduction in the required C/I corresponds to a substantial reduction in the required frequency re-use distance compared to present mobile telephone systems. As is summarized in Table I [Uddenfeldt, 1985] around three times improvement in spectrum utilization is obtained.

TABLE I – *Spectrum efficiency for companded FM system and two digital narrow-band FDMA systems. Sectorized cells with 3 cells per site are used*

	Analogue system	Digital system	Coded digital system
Description	Comp. FM	RELP/GMSK	RELP/GMSK
Speech coder rate (kbit/s)	–	16	16
Transmission rate (kbit/s)	–	16	27
Channel spacing (kHz)	25	15	25
Minimum C/I in fading (dB)	18	20	13
Frequency re-use:			
– No. of frequency groups	21	27	9
– No. of sites	7	9	3
Spectrum efficiency:			
– No. of channels per MHz and cell	1.9	2.4	4.4
– Capacity per cell for 10 MHz system (erlang)	12.4	17.2	35.1

This is of course no general result. Further improvements in analogue mobile telephone systems have not been considered, but on the other hand, large further improvements in technologies for digital speech transmission over fading radio channels can be expected.

3. Frequency economy implications of introducing wide-band radio channels

One major complication in going over to wide-band radio channels is time dispersion. The final result on the system level might be either a degradation or an improvement in frequency utilization through the influence of time dispersion (or frequency selective fading) on the required $C/I_{co\text{-}channel}$.

Under typical propagation conditions, the modulation bandwidth is considerably larger than the coherence bandwidth. Suitable signal processing could take advantage of this condition by introducing frequency diversity to reduce the required fading margin for multipath fading. The negative consequence might be that the effect on receiver sensitivity (required C/I) from time dispersion (inter-symbolic interference) could not be fully eliminated through suitable signal processing (i.e. adaptive channel equalization).

Much further study is needed, both of the detailed wide-band characteristics of the mobile radio channel and of suitable signal processing to take advantage of or combat time dispersion. The effects will also depend on the total system configuration, i.e. system data rate, other diversity arrangements, channel coding and basic type of radio modem. Frequency diversity could also be introduced through coordinated frequency hopping between the channels allocated to a cell.

An advantage of different combinations of TDMA and packet transmission is increased system flexibility, especially if different non-voice services become an important part of future systems. An obvious disadvantage of present FDMA systems is allocation of unnecessarily large channel capacity for narrow-band data transmission and for certain types of signalling. (However, an advantage of a wide-band channel system is the possibility of accommodating bursts of high speed data, i.e. 16 kbit/s ISDN messages. Also digital speech interpolation (DSI) like arrangements might be incorporated.)

The introduction of TDMA/packet results in much improved system signalling. A radio terminal can exchange system signalling with the base station without interruption of speech and data transmission, using separate time slots. The terminal can also check the signal level from nearby cells (momentarily switching both to a new time slot and radio channel). The frequency economy could be improved both through macro diversity between cells to reduce the required fading margin for shadowing and through rapid dynamic channel re-allocation when C/I becomes marginal. Such a system can be designed for a lower average $C/I_{co\text{-}channel}$, and the co-channel cells can be packed closer together, resulting in improved spectrum utilization.

On the other hand, the introduction of TDMA means a basic penalty in frequency economy due to overheads for guard bands between time slots and for burst synchronization.

4. Adaptation of the system specification to ease the practical implementation

4.1 *Reduced system selectivity*

Analysis of the interference situation in a cellular system with suitable control of terminal transmit power and close to optimal hand-over procedures, indicates much reduced mutual interference in the direction, terminals to base, compared to the situation where small independent systems, with overlapping geographic coverage but different base station sites, share the same frequency band. The system selectivity requirements on terminal transmitters and base station receivers could probably be reduced to around 40 dB without any noticeable increase in the $(C/I)_{co\text{-}channel}$ required for acceptable quality.

The interference situation would be roughly the same in the opposite direction if no dynamic power control is applied to the base station transmitters. A simple way to implement high dynamic range (blocking performance) of the terminal receivers might be to introduce automatic gain control.

A possible complication might be the introduction of power control at the base station transmitters in order to reduce the average level of co-channel signals, thus reducing the probability for harmful co-channel interference. One consequence would be requirements for more stringent specifications on transmitter intermodulation.

Reduced requirements on system selectivity would have a considerable influence on equipment cost and size through reduced requirements on dynamic range, noise performance and filter selectivity of different transmitter and receiver sub-systems. Present extreme requirements on spurious suppression have led to complicated receivers, using several stages of mixing and filtering. Reduced selectivity requirements might give important simplifications such as balanced circuits to suppress spurious emissions and direct conversion between base band and transmit frequency.

4.2 *Increased channel bandwidth*

The introduction of wide-band time-division radio channels will have a considerable impact on the practical implementation.

The cost of the concentrated base station sites will be reduced as each radio channel equipment will be shared by several speech or data channels. A reduced number of more widely separated radio channels will lead to a considerable reduction of the multiplexer complexity. Outside of the major metropolitan areas, the required traffic capacity of a base station site could be served by one wide-band radio channel, eliminating the need for multiplexers.

Considering base station complexity, the optimum system data rate would be a compromise between the needs of the major population centres and the more sparsely populated areas, and also a compromise between the early phase of system growth and the final saturated system.

A more important impact will probably be on the terminal's cost and size, as the terminal's cost is typically the major part of the total cost of a cellular system. Introduction of wide-band radio channels leads to a reduction of the requirements for extreme frequency stability, narrow radio-frequency filters and VCOs with good noise and microphony performance. Also the frequency synthesizer design is simplified, especially if there is a system requirement for fast switching between radio channels.

Reduced system selectivity and increased channel spacing impact mainly on the analogue and very high frequency sub-systems. This is of special importance as remaining digital sub-systems, including digital signal processing, can take full advantage of further developments in custom digital VLSI. Eventually, this might lead to the situation that those sub-systems that could not be realized in digital VLSI, will become the dominating cost and size factors of the terminal electronics.

However, introduction of wide-band radio channels also introduces system limitations and design problems. Too wide radio channels would not be practical.

- In many parts of the world and for many services, digital cellular systems for telephony or for dispatch must be introduced gradually into frequency bands presently organized for, and partly occupied by, narrow-band FDMA channels. A possible compromise might be to use intermediate bandwidth radio channels, i.e. combine FDMA and TDMA with around 300 kHz channel spacing, and to use a combination of frequency and time duplex (frequency duplex to adapt to the present frequency allocation principles and time duplex to eliminate the duplex filter from portable terminals).

- Time synchronization between different cells would probably be required.

- TDMA, and especially packet arrangements with retransmission of lost packages will introduce delays. Delays will also be introduced by the speech coder and channel coder. Echo cancelling will probably be necessary also in local and regional mobile telephone networks.

- Due to the use of a burst transmission with low duty cycle, the peak power will be much higher than the average terminal transmit power. The possibilities for considerably reducing the fading margin for multipath and even part of the shadow fading, as has been suggested above, will however reduce the requirements on average transmit power. (That also helps to reduce the battery size of portable terminals.) Using intermediate bandwidth radio channels ("narrow-band TDMA") the net result could be only moderately higher peak power than the CW power of present terminals.

- Going over to more wide-band radio channels which would probably require more complex circuits to utilize or combat the time dispersion, could result in excessive power consumption of the radio modems, especially considering portable terminals. Unfortunately, further improvements in the packing density of digital VLSI will probably not result in equal progress in reduced power consumption per elementary function. Even with CMOS, the power consumption will be considerable, if very high speed logic must be used. As portable telephones would be a major part of future cellular systems for important markets, the consequences on power consumption should be thoroughly considered before deciding on the width of the radio channels in a digital mobile telephone system.

5. Conclusions

This Report has tried to indicate that new technologies both on the system and practical implementation side could make it possible to combine improved system performance, especially frequency economy, with reduced system cost and reduced size of portable terminals. Key areas to consider the optimum system selectivity and channel spacing. A very tentative suggestion made in the Report is that a "narrow-band TDMA" system using digital speech transmission and a channel spacing around 300 kHz is an interesting possibility that merits further study. An important area that should be studied is the detailed characteristics of the wide-band mobile radio channels, including appropriate mathematical models and channel simulators.

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REPORT 741-3

MULTI-CHANNEL LAND MOBILE SYSTEMS FOR DISPATCH TRAFFIC (WITH OR WITHOUT PSTN* INTERCONNECTION)

(Question 37/8)

(1978-1982-1986-1990)

Introduction

Radio spectrum allocated for dispatch traffic is becoming increasingly congested and already many users (networks) have to share a channel with several other users. This practice employs the channel more effectively but gives the participants a reduced "grade of service" in the sense that they may often have to wait for some time for a channel to become free and they suffer from reduced privacy. Not only improved channel utilization but also better grade of service and good privacy conditions are important factors to design dispatch systems.

Part A of this Report deals with the general aspects of multi-channel land mobile systems for dispatch traffic, such as system configuration, characteristics of dispatch traffic, grade of service, traffic handling capability, performance of trunked systems, signalling and so on.

Part B of this Report introduces some systems being installed or planned by some administrations.

For this purpose of this Report, "dispatch system" has the meaning: A radio system used to control the operation of a fleet of mobiles, such as air craft, taxis, police, etc., and "trunked system" has the meaning: A multi-channel system with automatic channel selection, particularly referring to dispatch systems.

However, this Report does not consider the detail of interconnection of trunked dispatch systems with public or private switched telephone networks. Such interconnection requires further study.

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* Public switched telephone network.