SELECTIVE PERSONAL CALLING ON THE VHF-FM TRANSMITTERS

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Several modulation systems used on various radio networks in the world make it possible to operate selective calling and information transmission. Some of the selective calling systems operate on independent radio networks established for this purpose. Transmission is possible only on internationally licenced frequency bands which can generally be found in the VHF range. Some of the systems are also able to transmit a short voice message in addition to selective calling.

In another case VHF-FM transmitters are used for selective calling and/or voice message transmission. In order to realize this, other so-called auxiliary channels besides the main program-diffusing mono-, stereo and SCA sound channels are used to transmit messages. A selective calling system realized in auxiliary channels can be either public or private. In auxiliary channels, besides selective calling, numerical or audio frequency information can also be transmitted in principle.

A selective calling system on broadcasting transmitters can be operated within a radius of 30 to 50 kms of the coverage area. A way of practical realization of a paging network in our country can be an auxiliary modulation of broadcasting transmitters in the VHF range. The use of VHF transmitters for this purpose may be particularly effective if the system is to be operated not only in the coverage area of a transmitter, but in the whole country.

The use of home VHF transmitters for this purpose and some system-technical problems of measuring the network will be discussed below. Some of the problems are connected with the frequency allocation of auxiliary channels and with modulation parameters, while others are related to the determination of the signal-to-noise ratio at the receiving end and of the coverage area.

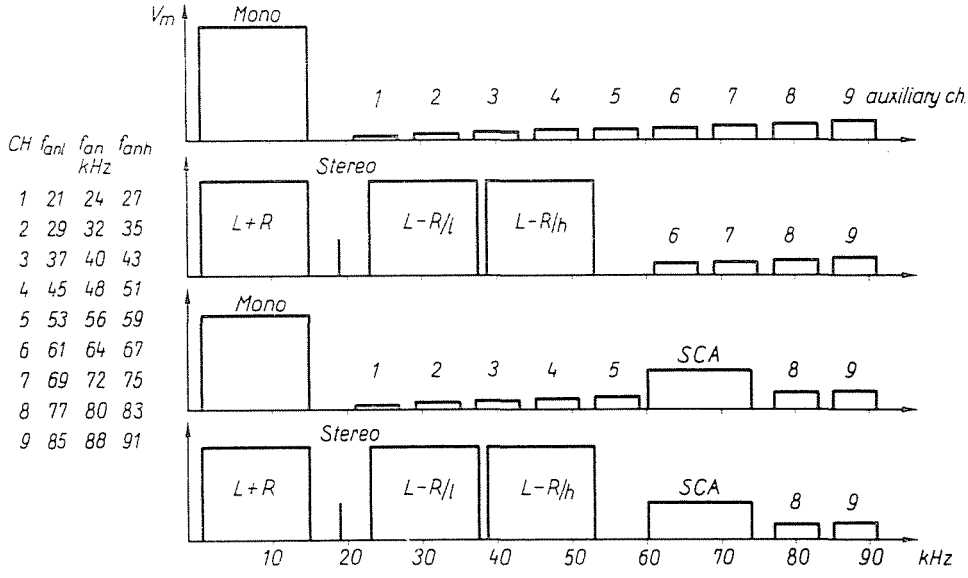
Frequency allocation of auxiliary channels

In the case of home VHF-FM transmitters 90 kHz is the highest possible modulation frequency. Among currently used modulation systems in broadcasting, the monophonic broadcast needs a bandwidth of 15 kHz, while the stereophonic broadcast a bandwidth of 15 + 30 = 45 kHz. Theoretically, SCA transmission can also be taken into consideration, which needs a 14 kHz bandwidth.

Accordingly

— in monophonic broadcasts 75 kHz,
— in mono + SCA broadcasts 61 kHz,
— in stereophonic broadcasts 45 kHz,
— in stereo + SCA broadcasts 31 kHz

modulation bandwidths are unused. The unused bands permit several auxiliary channels to be built in. The channels differ from each other in the carrier frequency. The most important task of the channels is to transmit the code numbers of selective calling. Moreover, the transmission of other, first of all numerical (or voice message) information must also be possible. Considering the interference of channels and the selectivity problems of the auxiliary channels in pagers, the channel allocation of 8 kHz was considered acceptable. This means that altogether 9 auxiliary channels can be operated in the modulation range (up to 92 kHz with a 2 kHz overstep). Figure 1 shows the



CH	f_{anl}	f_{an} kHz	f_{anh}
1	21	24	27
2	29	32	35
3	37	40	43
4	45	48	51
5	53	56	59
6	61	64	67
7	69	72	75
8	77	80	83
9	85	88	91

Fig. 1. Frequency allocation of auxiliary channels

channel allocation and band limits with their supposed transmission modes taken into consideration. Within the 8 kHz bandwidth channels the information bandwidth is only ± 3 kHz, the channels are separated by a 2 kHz safeguard band on each side.

Auxiliary channel modulation

The selective calling system uses double modulation. First the information to be transmitted modulates the auxiliary carrier, then the auxiliary carrier modulates the carrier wave.

The first modulation can be either AM or FM, the second, of course, only FM. But in the case of the first modulation, the use of FM is much more advantageous for it provides significant gain in the signal-to-noise ratio during demodulation. The parameters of double modulation must be chosen so that the coverage area of the selective calling system equals, or possibly exceeds, that of the main program. Moreover, the receiving possibilities of the main program must not be disturbed beyond a negligible extent by the auxiliary program.

The selective tone call of the auxiliary program is carried by a frequency of 1000 Hz. This tone produces a frequency stroke of $\Delta Fa = \pm 1.5$ kHz in the auxiliary channel.

The system values according to the symbols in Figure 2 are as follows.

We wish an output S/N of 20 dB in the auxiliary channel at $f_0 = 1000$ Hz. In this case

$$\frac{\gamma_0}{\gamma_{an}} = 3\frac{F_{an}^2}{f_0^2} = 6.75 \div 8.3 \text{ dB},$$

i.e., an input S/N of $20 - 8.3 = 11.7$ dB in the auxiliary channel is sufficient.

The output S/N of the first demodulator is dependent on the IF of the auxiliary channels as well as on the frequency stroke produced by the auxiliary carrier. If the stroke is changed properly, the signal-to-noise ratio remains constant.

For the first ($n = 1$) channel, if $F_{an} = 595$ Hz (where $B_c = 200$ kHz is the IF bandwidth of the receiver):

$$\frac{\gamma_{an}}{\gamma_c} = 3\frac{\Delta F_{an}^2 \cdot B_c}{f_{anh}^3 - f_{anl}^3} = 1.54 \cdot 10^{-2} \qquad \text{(a)}$$

from which

$$\gamma_c = \frac{\gamma_{an}}{1.54 \cdot 10^{-2}} = 438 \div 26.4 \text{ dB} \qquad \text{(b)}$$

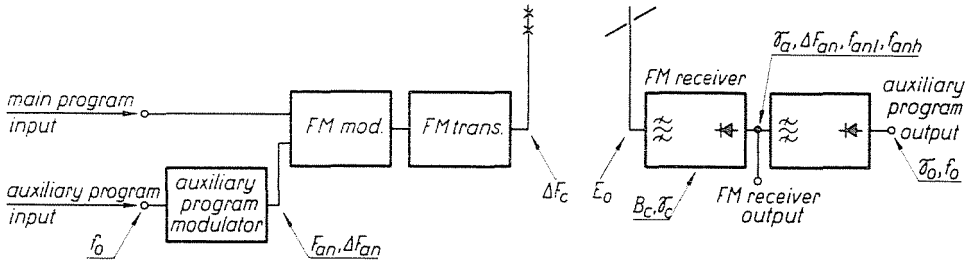


Fig. 2. System diagram of selective calling. f_0 — auxiliary program modulation frequency; ΔF_{an} — n-th auxiliary program stroke; F_{an} — n-th auxiliary program carrier frequency; ΔF_c — UHF—FM transmitter stroke; E_0 — receiving field strength; B_c — IF bandwidth of FM transmitter; γ_c — S/N of FM transmitter; γ_{an} — input S/N of n-th auxiliary program; γ_0 — output S/N of auxiliary channel; f_{anl}, f_{anh} low-high end of n-th auxiliary channel

Table 1

n	ΔF_{an} (Hz)	n	ΔF_{an} (Hz)
1	595	5	1382
2	791	6	1579
3	988	7	1776
4	1185	8	1974
		9	2171

In (a) the ratio $\Delta F_{an}^2 \cdot (f_{anh}^3 - f_{anl}^3)^{-1}$ must be kept constant. The ΔFa carrier-strokes necessary for the constant signal-to-noise ratio in each channel are stated in the Table 1. If only one, or perhaps 2 or 3 auxiliary channels are used at the same time, they insignificantly load the $\Delta F_{max} = 50$ kHz stroke permissible for VHF – FM transmitters. (For the maximum stroke of the main program must be reduced by that of the auxiliary channel.) In general, however, the average stroke is not higher than 12 to 16 kHz.

Range of the coverage area

According to equation (b) a signal-to-noise ratio of 26.4 dB is necessary before the demodulator of the VHF – FM receiver. Supposing a receiver of average quality, a 6 μV input voltage is enough for that S/N. But in the case of the selective paging system only the use of a very short dipole antenna—compared with the wave-length—can be considered. The receivers used in measuring the system can ensure the expected S/N ratio in an ambient field strength of 8 μV/m.

In the case of actual receiving, however, several components reducing the field-strength must be taken into account. The open-air field strength, e.g., is

reduced by buildings, electric cables and wires, etc., and there are also several industrial disturbances present. From time to time the signals may fade, too, owing to multipath propagation and atmospheric absorption.

Measurements were performed in some 600 different places in Budapest and its neighbourhood to determine the disturbing factors numerically. The field-strength inside buildings was found to be on the average about 10 dB (max. 28.2 dB) less than outdoors. In the same way, voices deriving from noise sources in the UHF range were studied. On the basis of measurements under good receiving conditions about 8 to 10 μV/m, under noisy conditions field strengths of about 80 to 100 μV/m were found to be sufficient. It was established that a selective calling system could be operated sufficiently.

Experimental system

An experimental selective calling system was worked out to collect operating data. The system was operated on two VHF—FM transmitters (Budapest and Kabhegy). Kabhegy was the repeater station broadcasting the signal of the auxiliary channel on its own carrier wave. There were 10 small VHF—FM receivers in the system, each with a different code number. (The developed version of the receivers will contain matchbox-sized *RF*, *IF* and demodulator units.)

The receivers operated perfectly in Budapest. Some 100 km was the longest transmission distance studied. The effect of the auxiliary channel on the main program was negligible. The presence of the auxiliary program could not be detected by subjective reception study. No decrease of the signal-to-noise ratio in the main program could be measured by selective level meter up to 8 kHz, and even in higher frequencies the noise level increased only by 2 to 3 dB. Thus, the effect of the auxiliary program was found negligible. The experience with the experimental system elaborated by the Chair of Microwave Communication demonstrated that a local or a nation-wide selective calling system operated on home VHF—FM transmitters can be realized.

Summary

On VHF—FM transmitters, besides the main program-diffusing mono- and stereo sound channels, other, e.g. a selective personal calling system can also be operated. In the Chair of Microwave Communication of the Polytechnical University of Budapest a selective personal calling system to be operated on the home VHF—FM transmitters was worked out. The preliminary operation carried out with some elements of the system—modulators, receivers, etc.—was successful.

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